ARMY RESEARCH LABORATORY

Baseline Skills Assessment of the US Army Research Laboratory

by Josephine Q Wojciechowski

ARL-TR-7181 **January 2015**

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Office of the Director, ARL

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14. ABSTRACT
The US Army Research Laboratory (ARL) started several corporate initiatives to benchmark and improve upon strategic areas of the laboratory. These initiatives, designed to investigate a critical interest area, each began with a study led by a senior leader. The intent was to propose recommendations and an implementation plan for the next several years. One of these initiatives, Skills Assessment, was designed to examine the current state of the human capital of the organization. Dr Laurel Allender, director of the Human Research and Engineering Directorate, was tasked to lead a team of representatives from each of the other directorates in ARL and appropriate support functions in assessing the human capital of ARL. At the same time, ARL began a process to realign the long-term direct mission program to a set of science and technology campaigns. The ARL campaign plans would be collaborative and crosscutting focus areas for the mission program. The team used the campaign taxonomy to define the competencies for ARL and collected data for each ARL scientist or engineer, including all post docs and contractors based on the competency lists. A gap analysis was then completed. There were areas where ARL has little competency but planned to lead or collaborate in that area as well as areas where we had large numbers of people claiming competency yet we did not plan future efforts. Although the data were not exact, the study provides a place to begin to benchmark the ARL skill mix.

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Additionally, this effort would not have come together without the guidance from Dr Laurel Allender, and Mr John F Lockett, when she was detailed to another position. Their guidance and direction were paramount to the success of this assessment.

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1. Introduction

In the fall of 2013, the US Army Research Laboratory (ARL) began several corporate initiatives to benchmark and improve upon the most strategic areas of the laboratory. These initiatives were to begin with a study led by a senior leader and designed to investigate a critical interest area. The outcome of the study would be a recommendation plan to be implemented over the next several years.

One of these initiatives, titled “Skills Assessment”, was designed to examine the current state of the human capital of the organization. Dr Laurel Allender, director of ARL’s Human Research and Engineering Directorate (HRED), was tasked to lead a team of representatives from each of the other directorates and appropriate support functions in ARL to assess the human capital of ARL. Team members are listed in Table 1.

Table 1 Skill assessment corporate initiative team members

Organization	Name
Director lead	Dr Laurel Allender/Mr John Lockett
Office of the Director support	Ms Sue Hickman
	Ms Diane Hawkins
	Dr Val Emery
	Ms Jackie Laroche
	Ms Natalie Simon
Army Research Office representative	Dr Tom Doligalski
Computational and Information Sciences Directorate representative	Dr Barbara Broome
Human Research and Engineering Directorate representative	Dr Don Headley
	Dr Tom Davis
	Ms Jody Wojciechowski
Sensors and Electron Devices Directorate representative	Dr Nasser Nasrabadi
Survivability/Lethality Analysis Directorate representative	Mr John Beilfuss
Vehicle Technology Directorate representative	Dr John Wilkerson
	Mr Ed Habtour
Weapons and Materials Research Directorate representative	Dr Paul Weinacht

At the same time, ARL began a process to realign the long-term direct mission program to a set of science and technology (S&T) “campaigns”. The ARL campaign plans would be collaborative and crosscutting focus areas for the mission program. The 8 campaigns, shown in Fig.1, are as follows:

- Extramural Basic Research
- Human Sciences
- Information Sciences

- Sciences for Lethality and Protection
- Sciences for Maneuver
- Materials Research
- Computational Sciences
- Assessment and Analysis

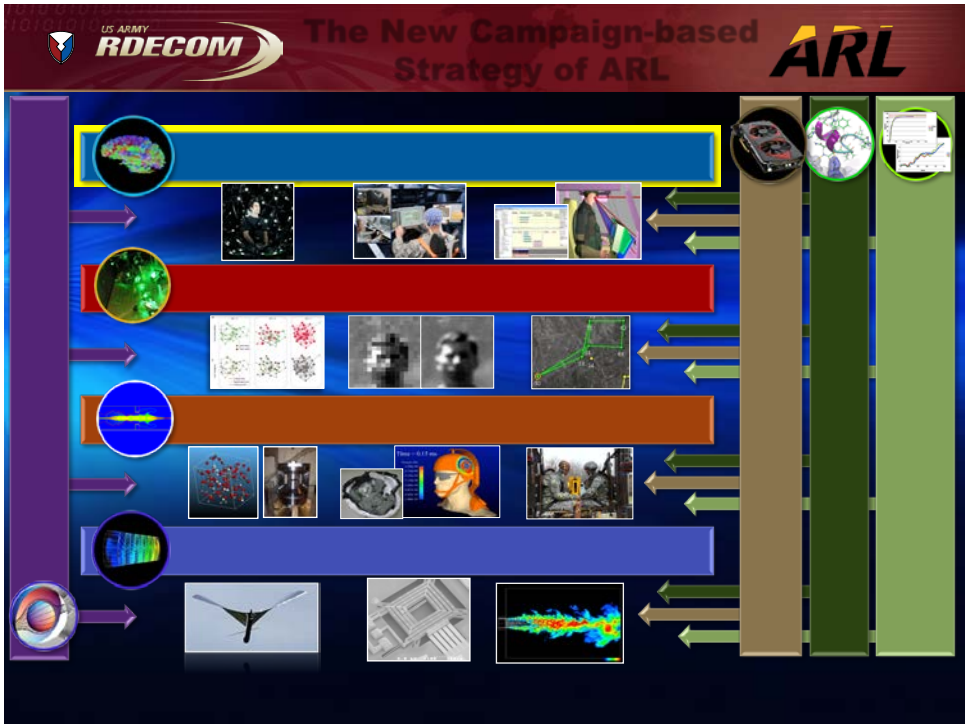


Fig. 1 ARL campaign plans

To relate the current skill set to the future needs of the ARL, the campaign plans were referenced as the future mission program. This report summarizes the results and recommendations of the skills assessment corporate initiative study.

2. Background

The first step in completing a skill assessment was to define skill. Many different sources were researched to determine how to define skill. The US Office of Personnel Management (2014) defines knowledge, skills, and abilities (KSAs), or competencies, as

> the attributes required to perform a job and are generally demonstrated through qualifying experience, education and training. Knowledge is a body of information applied directly to the performance of a function. Skill is an observable competence

> to perform a learned psychomotor act. Ability is the competence to perform an observable behavior or a behavior that results in an observable product.

It was this definition of competency or KSAs that we were hoping to capture in our analysis.

A decision was made early on to focus on the scientists and engineers (S&Es) in the laboratory. There were Army-level and Department of Defense–level efforts underway to look at competencies in different areas of the workforce. These efforts initially began with a focus on human resource personnel. Additionally, there was discussion about measuring skills in terms of leadership. As this presented a different level of effort, it was decided to focus on the S&E workforce for the initial study.

Personnel records were examined for data already on hand that could be used to evaluate competencies. Education is captured in the degrees achieved by ARL employees. Just having a degree does not, however, capture any qualifying experience. We considered using position descriptions but these do not capture the specific area that individuals work. Additionally, each employee is assigned a specialty work code (SWC). These are meant to better describe the work that the employee is doing. However, SWCs varied greatly from directorate to directorate. One directorate had 63 SWCs while another had basically 1. These did not capture competency either.

About this time, the US Army Research, Development and Engineering Command (RDECOM) published a survey of all its staff and subordinates to understand competencies and potential areas of overlap between the RDECOM components. This survey was very thorough, but because they were looking across the entire command, the level of competency breakdown was not sufficient for our purposes.

The search for a competency list brought us to the campaign plans and its taxonomic breakdowns. Because the campaign plans' level 3 taxonomy seemed to describe the competencies of the laboratory, it was decided that we would use the level 3 taxonomy where we could. For the Sciences for Lethality and Protection (SLaP) Campaign, the level 3 taxonomy was not as detailed a taxonomy than the other campaigns. A more detailed list of competencies was generated by the representative from the Weapons and Materials Research Directorate (WMRD). The list was vetted by representatives from the directorate and used to collect competency data.

The level of expertise ARL might have in each of the competency areas was also important to this assessment. One might have a competency area where he/she is an expert while another person might just be out of college without much experience. It was decided that for each competency reported, one should indicate the individual's proficiency in that area. A 3-level proficiency breakdown was used in this assessment. The proficiency levels are described in Table 2.

Table 2 Proficiency level definitions

Level	Definition
1	Basic understanding, minimal experience
2	More specific understanding, some level of application
3	Expertise, experienced in the field

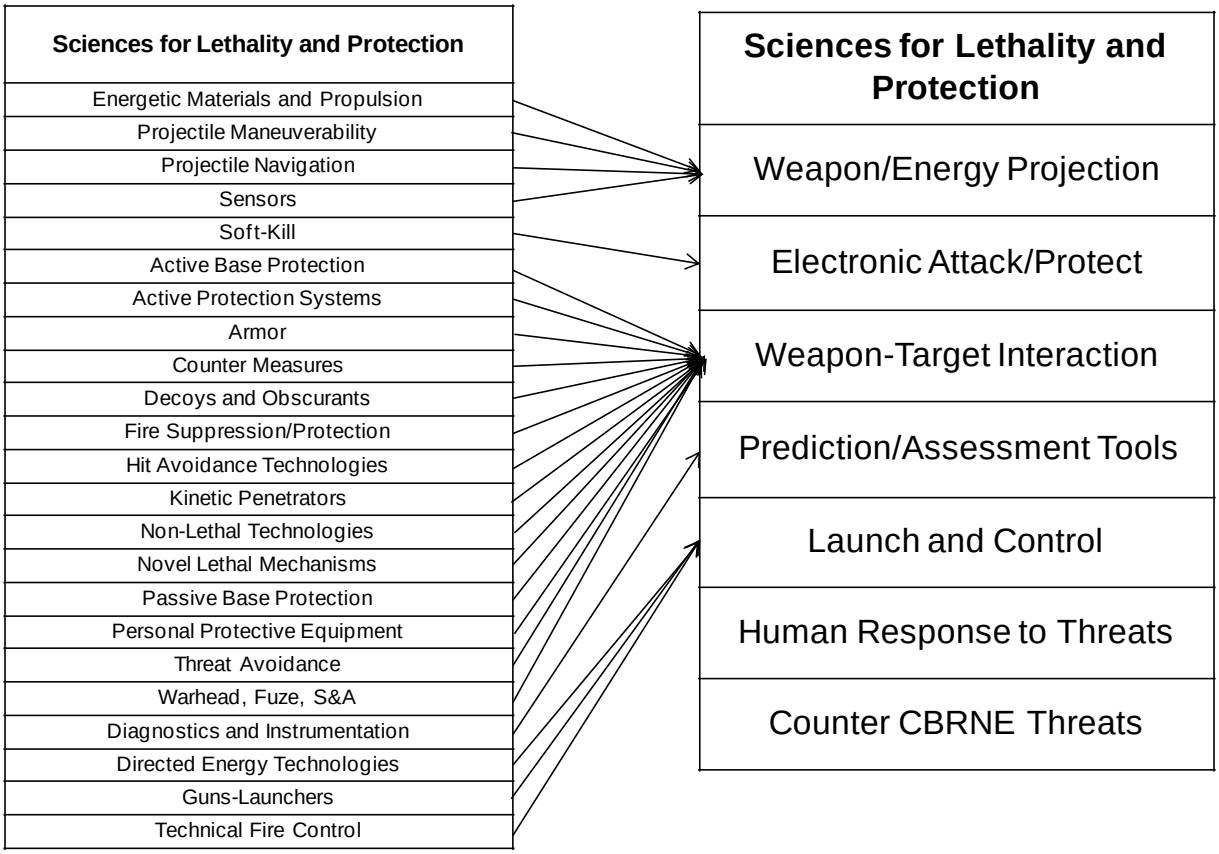
3. Method

Once the decision was made to collect competencies by campaign plans, we created an Excel spreadsheet to collect skill competency and proficiency data for each scientist and engineer in ARL. The spreadsheet contained information for each S&E civilian that described one's position and location in ARL. The list was sorted by branch, and branch chiefs were asked to identify the appropriate competency(s) for their employees and the proficiency level of those competencies. They were allowed to identify up to 3 competencies for each employee from the complete list covering all campaigns and add a "write-in" competency if there was not one from the list that fit. They were then asked to add any contractors and/or post docs without attaching personal information to them to avoid contractual legal issues. Tables in Appendix A have the list of competencies by campaign. Once the data were collected, the results were summarized.

Several assumptions were made in collating the data. If proficiency level was not indicated by the branch chief, it was assumed to be level 3. This was done because in many of the instances where proficiency was left off, the competency listed was the only competency or a write-in competency. In these cases, one would assume that the individual would have expertise in this field.

We wanted to look at our competencies (areas) as a function of whether the ARL would lead, collaborate, or follow. Unfortunately, these designations on the campaign plans were made at level 4 of the taxonomy and we had collected competency data at level 3. Where we could get agreement from the campaign plan representatives, we determined what the level 3 designation would be. Where we were unable to coordinate with the campaign representatives, we weighted the level 4 categories of lead, collaborate, or follow to determine the designation at level 3. For the SLaP Campaign, we had used a list provided by WMRD instead of the campaign level 3 taxonomy. We mapped that list to the SLaP Campaign level 3 taxonomy. That mapping is shown in Fig. 2. This mapping was completed to show how the competency list we used to collect data related to the actual SLaP Campaign level 3 taxonomy. Data are presented for both the competency list and the mapping to campaign taxonomy.

The write-in competencies allowed for each employee, whether government employee or post doc/contractor, were consolidated by campaign based on key words.



Note: CBRNE = chemical, biological, radiological, nuclear, and explosives

Fig. 2 Mapping from the competency list used to collect data to the level 3 categories for the Sciences for Lethality and Protection Campaign

4. Results

Our data are summarized by directorate, campaign and proficiency level, and by civilian versus post doc versus contractor. Values provided in the tables and graphs represent the number of instances the competency was reported.

Table 3 shows the number of instances of competencies each directorate identified in each of the campaigns. These numbers are summarized at the campaign level 1. As an exemplar for one campaign, a breakdown of competencies within the Extramural Basic Research Campaign is shown in Fig. 3. Similarly, Table 4 shows the number of instances the Extramural Basic Research Campaign areas were chosen as a function of status of employee: civilian, post doc, or contractor.

Table 3 Number of instances of competencies by campaign for each directorate

Campaign	ARO	CISD	HRED	SEDD	SLAD	VTD	WMRD	ODIR	LABOPS
Number of personnel surveyed	39	224	220	326	358	78	608	13	18
Extramural basic research	48	16	4	36	4	0	50	5	9
Human sciences	7	21	420	1	3	0	21	2	3
Information sciences	1	182	7	145	1	0	4	1	0
Sciences for lethality and protection	1	4	1	49	170	0	449	8	5
Sciences for maneuver	0	54	18	26	7	132	39	0	23
Materials research	14	25	5	374	32	39	443	5	2
Computational sciences	1	246	14	3	40	0	63	1	0
Assessment and analysis	2	36	85	6	595	14	22	8	0

Notes: ARO = Army Research Office, CISD = Computational and Information Sciences Directorate, HRED = Human Research and Engineering Directorate, SEDD = Sensors and Electron Devices Directorate, SLAD = Survivability/Lethality Analysis Directorate, VTD = Vehicle Technology Directorate, WMRD = Weapons and Materials Research Directorate, ODIR = Office of the Director, LABOPS = Laboratory Operations

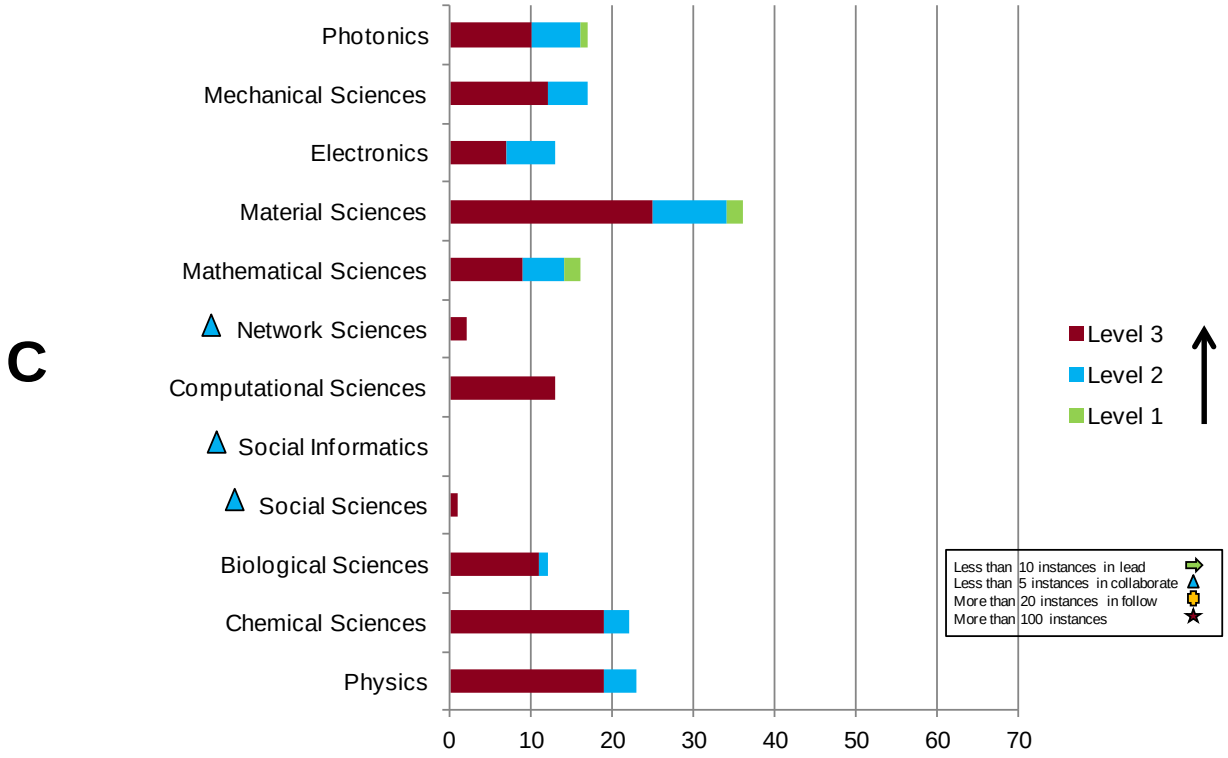


Fig. 3 Instances chosen for Extramural Basic Research Campaign competencies

Table 4 Personnel choosing Extramural Basic Research Campaign competencies

Extramural Basic Research	Civilians	Post Docs	Contractors	Total
Photonics	16	…	1	17
Mechanical sciences	15	…	2	17
Electronics	13	…	…	13
Materials research	34	1	1	36
Mathematical sciences	15	1	…	16
^Network sciences	2	…	…	2
Computational sciences	9	2	2	13
^Social informatics	0	…	…	0
^Social sciences	0	…	1	1
Biological sciences	11	…	1	12
Chemical sciences	14	2	6	22
Physics	21	…	2	23

^Less than 5 instances in a collaborate area

Branch chiefs were given the option of providing one write-in competency if they felt that the list did not sufficiently describe the competencies of their employees. The write-in competencies were summarized by the campaign plan area where it was believed they belonged. The list for the Extramural Basic Research Campaign is shown in Table 5.

Table 5 Write-in competencies assigned to Extramural Basic Research Campaign

Competency	Total
Fundamental research—laser induced breakdown spectroscopy	1
Mechanical sciences	1
Mechanics and materials	1
Photonics	1
Physics	4
Statistical analysis	2
Theoretical and numerical chemistry	1
Quantum chemistry	1
Optimization in chemical compound space	1
Fundamental research—extramural basic research	35
Condense matter physics	1
Device physics	2
Multidisciplinary organic synthetic chemical and biotechnology	1
Multidisciplinary analytical chemistry electrochemistry and bio	1
Multidisciplinary analytical chemistry/spectroscopy and biotechnology	1
Multidisciplinary physics and biotechnology	2
Photonics and lasers	1
Quantum sciences—basic physics	1

Data for all campaigns are provided in Appendixes B–I by campaign. In the figures, each colored bar indicates level of proficiency (level 3 is the highest). The areas that ARL will lead are identified by the "L" to the left of the y-axis labels. The areas in which ARL will collaborate are identified by the "C" to the left of the y-axis labels and separated from the "Lead" area by a horizontal line. The campaign areas in which ARL will watch or follow are identified by "F" to the left of the y-axis label and separated from the collaborate area by a horizontal line. Items of interest are highlighted in each of these figures using symbols. When a campaign area that was considered a lead area had less than 10 instances identified, it was indicated with a green arrow. When a campaign area that was considered a collaborate area had less than 5 instances identified, it was indicated with a blue triangle. Similarly, areas we follow that have 20 or more instances identified were indicated with a yellow cross. Lastly, maroon stars indicated any area that had more than 100 instances identified. These markers are shown in the figure keys.

For the tables in the appendixes, the areas that ARL will lead are highlighted in green. The areas in which ARL will collaborate are highlighted in blue. The campaign areas in which ARL will watch or follow are highlighted in peach. Areas of interest are also indicated in these tables with symbols. When a campaign area that was considered a lead area had less than 10 instances identified, it was indicated with a greater-than symbol. When a campaign area that was considered a collaborate area had less than 5 instances identified, it was indicated with a carat symbol. Similarly, areas we follow that have 20 or more instances identified were indicated with a plus sign. Lastly, asterisks indicate any area that had more than 100 instances identified.

5. Discussion

It is important to note that the campaign plans were in development while this data collection was in progress. Some of the campaigns changed from the time that the data was collected until it was analyzed. That is why some of the areas are marked as "Not in the current taxonomy." Additionally, the Sciences for Lethality and Protection Campaign level 3 was not defined at the same level as the other campaigns, so the list shown in Fig. 2 was used and analysis was provided data for both the level 3 campaign and the list.

RDECOM had recently completed their survey and there likely was confusion by those who filled out the 2 surveys. RDECOM's survey was designed to understand the competencies at the Research, Development and Engineering Center level as opposed to the laboratory. It was apparent that the confusion as to the difference between the surveys may have impacted some of the competency selections.

Each campaign had data points that were of interest, and recommendations were derived from these indicators. The recommendations for each of the campaigns are discussed separately in the following paragraphs. Overall, of the personnel surveyed, 68% listed 2 competencies and 46%

listed 3 competencies. Only 17% provided a write-in competency. For the Extramural Basic Research Campaign (Appendix B), there are 3 areas identified as areas where potential gaps might be: Network Sciences, Social Informatics, and Social Sciences were all selected by less than 5 individuals. All areas in this campaign are collaboration areas; 3 areas were identified because they had less than 5 instances chosen.

In the Human Sciences Campaign (Appendix C), there were 3 areas indicated where additional competency may be needed. Two of the areas, Information and Delivery for Effective Learning and Training and Virtual Humans/Avatars were lead areas and had less than 10 instances of the competency selected. Computational Representation of Societies and Cultures is a collaborate area and had less than 5 instances of the competency selected.

The Informational Sciences Campaign (Appendix D) had 13 areas where additional competencies were needed. Seven of these were lead areas: Analysis and Identification of Threats, Stealthy Assessment of Adversarial Networks, Exploitation of Adversarial Network Vulnerabilities, Estimates of Adversarial Dynamics, Forecasts of Mission Environment, Distributed Collaborative Planning and Execution of Missions, and Adaptive Protocols. There were 6 collaborate areas: Effector Phenomenology, Highly Optimized Data Storage on Soldier-borne Devices, Risk Assessment of Networks, Planning and Analysis of Military Missions, Intelligent Adaptive Interfaces for Augmented Cognition, and Analysis of Imperfectly Observable Networks. Additionally, there was one lead area that may need additional definition. Sensor Phenomenology had more than 100 instances of competency selected.

Using the Sciences for Lethality and Protection level 3 taxonomy (see Fig. 2), there are 5 competency areas of concern (Appendix E). Two of these are in need of additional competency: Electronic Attack/Protect is a lead area with less than 10 instances and Human Response to Threats is a collaborate area with less than 5 instances. There were 3 areas where additional definition is indicated because more than 100 instances were reported. They are Weapon/Energy Projection, Weapon-Target Interaction, and Prediction/Assessment Tools.

The actual list used to collect data for Sciences for Lethality and Protection had 9 areas indicating that additional competencies were needed. Six of these were lead areas: Decoys and Obscurants, Fire Suppression/Protection, Hit Avoidance Technologies, Non-Lethal Technologies, Projectile Navigation, and Soft-Kill. Additionally, Active Base Protection, Technical Fire Control, and Threat Avoidance were collaborate areas that had less than 5 instances reported.

In the Sciences for Maneuver Campaign (Appendix F), there were only 2 areas that require consideration. Usage Management is a collaborate area that had less than 5 report instances of competency. This indicates that additional competencies are needed in this area. This campaign also had one area, Warfighter Support and Logistics, where more than 20 instances were identified in an area that was designated as a follow area. This is an indication that efforts should be redirected or shuffled to utilize personnel in an area where the laboratory is moving or

planning to move. Also, 29% of the instances in Warfighter Support and Logistics were from contractors. Shifting contractor efforts would provide some flexibility without having to recruit.

In the Materials Research Campaign (Appendix G), there were 11 areas in need of additional competencies. Eight of these were areas where ARL has stated that we should lead efforts in the field. Each of these 8 had less than 10 instances of competency: Ultra-Lightweight Metals, Chemical Specific Sensing, Sensor Protection Material, UV Optoelectronics, Quantum Information Science, Computational Biology, Bio-Sensors, and Fatigue. The other 3 areas were collaborate competency areas that had less than 5 instances. They are System Biology, High Strength Conductors, and Energy Absorbers.

The Computational Sciences Campaign (Appendix H) had only 3 areas of concern. Two of these were collaborate areas with less than 5 instances identified. They are Multi-Dimensional Analysis and Model Order Reduction. This campaign also had one area where more than 20 instances were identified in an area that was designated as a follow area. This is an indication that efforts should be redirected or shuffled to utilize personnel in an area where ARL is moving or planning to move. Also, 27% of the instances in Domain Specific Languages were from contractors.

The Assessment and Analysis Campaign (Appendix I) had 9 competency areas that were identified as needing attention. Six of these were area where a low number of instances were indicated. Three of the 6 were in lead areas where less than 10 instances were selected: Associated Systems Engineering (Smart Systems), Smart Systems, and Smart Technologies. Three were in collaborate areas where less than 5 instances were selected: Smart Platforms and Forces, RAM Assessment, and Effects of Multi- and Cross-Scale Phenomena. Additionally, 3 areas had more than 100 instances identified indicating that the competency area may need more definition. They were Electronic Warfare Assessment, Ballistic Assessment, and Verifying and Validating Assessment Techniques. The first 2 are lead areas, and the other is collaborate.

6. Conclusions and Recommendations

It is recognized that the data are not perfect. However, the areas highlighted in this analysis can be examined as areas of concern and a place to begin looking for restructuring the human capital of the laboratory. The survey and data analysis suffered from following on the heels of the RDECOM survey. The close time frame and different purposes of the 2 surveys caused some confusion and likely impacted responses. There is also the chance that some responses were political. Some likely responded with competencies they believed were politically correct, not their actual competency. For all these reasons, the data should be taken with a grain of salt but it does help to focus efforts. One should look at the areas identified as having too few or too many instances of competency and determine if this is actually a fact.

The study data should also be used by the campaign plans to reevaluate the competencies highlighted in the individual plans. In some cases, it appears that the campaign plans have identified certain competencies that they expect to lead, but there are few to no personnel assigned to these areas. The campaign plans should determine whether these are areas they truly need to lead (in which case, there needs to be future growth in personnel to support these areas) or whether they represent areas to collaborate or follow.

The study data also highlighted a number of competencies where there are a large number of personnel assigned to them. The campaign plans should consider a finer specification of the particular competencies within the larger competency. There was not a consistent number of competencies relative to the number of personnel in each campaign area, which may contribute to large numbers of personnel within a single competency. The effectiveness of this type of study depends on how well the competencies reflect the required skills within the campaign area.

One shortcoming of the study data was that it was impossible to determine whether a particular competency was adequately represented or oversubscribed especially if zero growth in laboratory staff is considered. While the study can provide guidance for those areas that require growth, it appears to be less helpful to defining those areas for contraction.

It is recommended that the survey be completed again once the campaign plans are finalized and the lead, collaborate, and follow areas have been well defined. Additionally, the purpose of the survey should be made clear to all to help prevent political answers. Clear communication of the campaign plan taxonomies, the areas for lead, collaborate, and follow, and the purpose of the survey will be important to improving the data collection. The survey itself was not difficult to complete and with a better understanding of the purpose, the quality of the data will improve.

It is also recommended that a similar assessment be completed for auxiliary and support services to ensure the required support staff is available and functioning. The best scientists in the world cannot make progress without computing services, contracting services, and the associated personnel and human resources. Also, some measure of leadership skills will be of benefit to the organization. ARL must be able to identify those individuals that have the best potential for leading the organization into the campaign plans.

7. References

US Office of Personnel Management: OPM.gov Main, Frequently Asked Questions, USAJOBS, What are KDA's? Washington (DC): US Office of Personnel Management; [accessed 2014 Jan]. http://www.opm.gov/FAQs/QA.aspx?fid=d5e0f29c-fcc1-4ee2-a9f1-67ef78c0dfe4&pid=e9430deb-2cdc-46a2-8746-0811d78bee9f&result=1.

Appendix A. Campaign Competency Selections

This appendix appears in its original form, without editorial change.

Extramural Basic Research
Physics
Chemical Sciences
Biological Sciences
Social Sciences
Social Informatics
Computational Sciences
Network Sciences
Mathematical Sciences
Materials Sciences
Electronics
Mechanical Sciences
Photonics

Human Sciences
Molecular biology, biochemistry, genetics and genomics
Brain structure-function coupling
Computational representation of cognition
Sensory perception
Physical and cognitive performance and resilience
Physical-cognitive interactions
Individual differences
Environmental effects
Multisensory integration
State sensing in the real world
Learning and experience
Computational representation of the human body
Motivation and emotion
Distributed cognition and decision making
Team dynamics
Training effectiveness
Personnel and leader development
Ethics and values
Social-cultural interaction
Social cognitive networks
Organizational structure and design
Computational representation of societies and cultures
Ergonomics and biomechanics
Physical augmentation
Multimodal displays and controls
Training technologies
Usability
Implantable materials and devices
Brain-computer interaction
Cognitive augmentation
Human-intelligent systems interaction
Wearable computing/systems
Human interaction with/in networked systems
Virtual humans/avatars
Information and delivery for effective learning and training

Information Sciences
Sensor phenomenology
Effector phenomenology
Atmospheric sensors and behavior modeling
Highly optimized data storage on soldier-borne devices
Uncooperative social sensing
Counters to highly stealthy cyber threats
Analysis and identification of threat TTPs
Risk assessments of networks
Stealthy assessment of adversarial networks
Exploitation of adversarial network vulnerabilities
Attack-resilient cyber operations
Pattern recognition and mapping
Recognition and classification of human activity
Estimates of adversarial dynamics
Forecasts of mission environment
Planning and analysis of military missions
Intelligent control of mission execution
Intelligent adaptive interfaces for augmented cognition
Analysis and fusion of heterogeneous information
Discovery and extraction of information from massive data sets
Distributed collaborative planning and execution of missions
Trust, consensus and influence
Soldier and system role/task allocation
Unconventional alternative channels
Adaptive protocols
Co-evolution/co-dependent behaviors of networks
Reconfigurable and self-adaptive networks
Analysis of imperfectly observable networks

Sciences for Lethality and Protection
Active base protection
Active protection systems
Armor
Counter measures
Decoys and obscurants
Diagnostics and instrumentation
Directed energy technologies
Energetic materials and propulsion
Fire suppression/protection
Guns-launchers
Hit avoidance technologies
Kinetic penetrators
Non-lethal technologies
Novel lethal mechanisms
Passive base protection
Personal protective equipment
Projectile maneuverability
Projectile navigation
Sensors
Soft-kill
Technical fire control
Threat avoidance
Warhead, fuze, S and A

Sciences for Maneuver
Energy storage
Conversion/power generation
Distribution/transfer
Intelligent energy and power
Structures
Mechanics and dynamics
Actuation and mechanisms
Platform concepts
Perception
Intelligence and control
Human machine interaction
Reliability
Mechanism state awareness (health)
Usage management
Warfighter support and logistics

Materials Research
Advanced platform structures
Propulsion
Ultra-lightweight metals
Polymeric materials
Structural energy materials
Hybrid, 3d composites
Structural materials-multiscale research
RF sensing and communication devices
Electronic warfare devices
RF metamaterials
Energy efficient, low power electronics
Infrared sensing material and devices
Chemical specific sensing
Sensor protection material
UV optoelectronics
High energy and advanced tactical lasers
Transformational optics and devices
Quantum information science
Photonics-multiscale research
Energy storage
Power generation and energy harvesting
MEMS and micropower
Fuel cells and fuel processing
Power distribution
Thermal sciences
Novel energy
Energy and power-multiscale research
Systems biology
Synthetic biology
computational biology
Bio/non-bio integration and interfaces
Bio-fuels
Bio-sensors
Bio and bio-mimetic materials
Advanced manufacturing
Additive manufacturing
Corrosion
Fatigue
Polymer coatings (CARC)
Green materials and processes
Energy fields coupled to matter
Extreme synthesis of novel materials
Lightweight and specialty metals
Ceramics and transparents
Composites and hybrids

Materials Research
Fabrics and wearables
High strength conductors
Energy absorbers
Penetrator and warhead materials
Energetics
Advanced mechanics
Weapons
Energy coupled to matter
High strain rate and ballistic materials-multiscale research

Computational Sciences
Multiscale/interdisciplinary predictive simulation
Complex integrated systems
Verification, validation and uncertainty quantification
Next generation scalable algorithms
Multi-dimensional analysis
Discrete systems
Real-time data access and analytics
Model order reduction
Tactical high-performance computing systems
Data intensive computing architectures
Next generation computing systems
High performance networking
Programming environments
Domain specific languages
Reusable software
Complex systems computing environment

Assessment and Analysis
Valuating investments in S and T
Forecasting discovery
Impact of discovery on innovation
Determinants of investment effectiveness
Impact of S and T on innovation and competiveness
Competitiveness of the S and T workforce
Verifying and validating assessment techniques
Effects of multi- and cross-scale phenomena
Synthesizing disciplines for holistic assessments
Ballistic assessment
Cyber assessment
Electronic warfare assessment
System of systems (DOTMLPF) assessment
Human factors assessment
Ram assessment
Smart technologies
Smart systems
Smart platforms and forces
Associated systems engineering (smart systems)

Appendix B. Extramural Basic Research Campaign Data

This appendix appears in its original form, without editorial change.

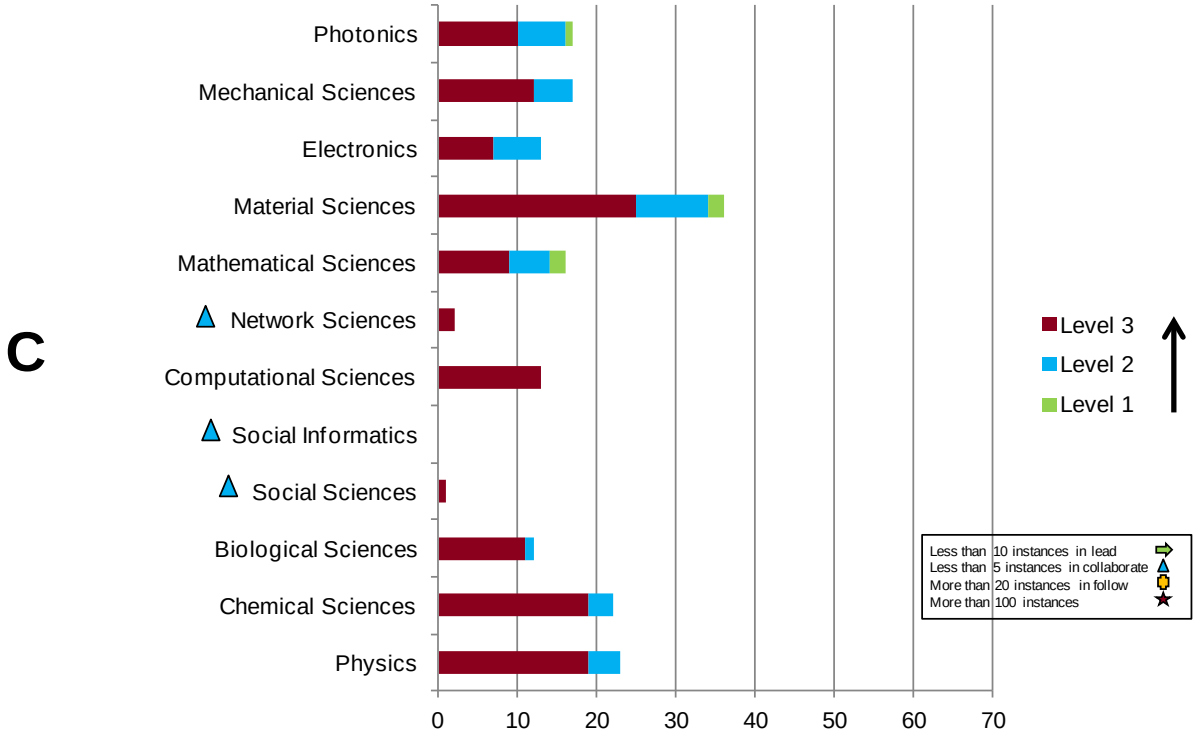


Fig. B-1 Instances chosen for Extramural Basic Research Campaign competencies

Table B-1 Personnel choosing Extramural Basic Research Campaign competencies

Extramural Basic Research	Civilians	Post Docs	Contractors	Total
Photonics	16	…	1	17
Mechanical sciences	15	…	2	17
Electronics	13	…	…	13
Materials research	34	1	1	36
Mathematical sciences	15	1	…	16
^Network sciences	2	…	…	2
Computational sciences	9	2	2	13
^Social informatics	0	…	…	0
^Social sciences	0	…	1	1
Biological sciences	11	…	1	12
Chemical sciences	14	2	6	22
Physics	21	…	2	23

^Less than 5 instances in collaborate

Table B-2 Write-in competencies assigned to Extramural Basic Research Campaign

Competency	Total
Fundamental research - laser induced breakdown spectroscopy	1
Mechanical sciences	1
Mechanics and materials	1
Photonics	1
Physics	4
Statistical analysis	2
Theoretical and numerical chemistry	1
Quantum chemistry	1
Optimization in chemical compound space	1
Fundamental research - extramural basic research	35
Condense matter physics	1
Device physics	2
Multidisciplinary organic synthetic chemical and biotechnology	1
Multidisciplinary analytical chemistry electrochemistry and bio	1
Multidisciplinary analytical chemistry/spectroscopy and biotechnology	1
Multidisciplinary physics and biotechnology	2
Photonics and lasers	1
Quantum sciences—basic physics	1

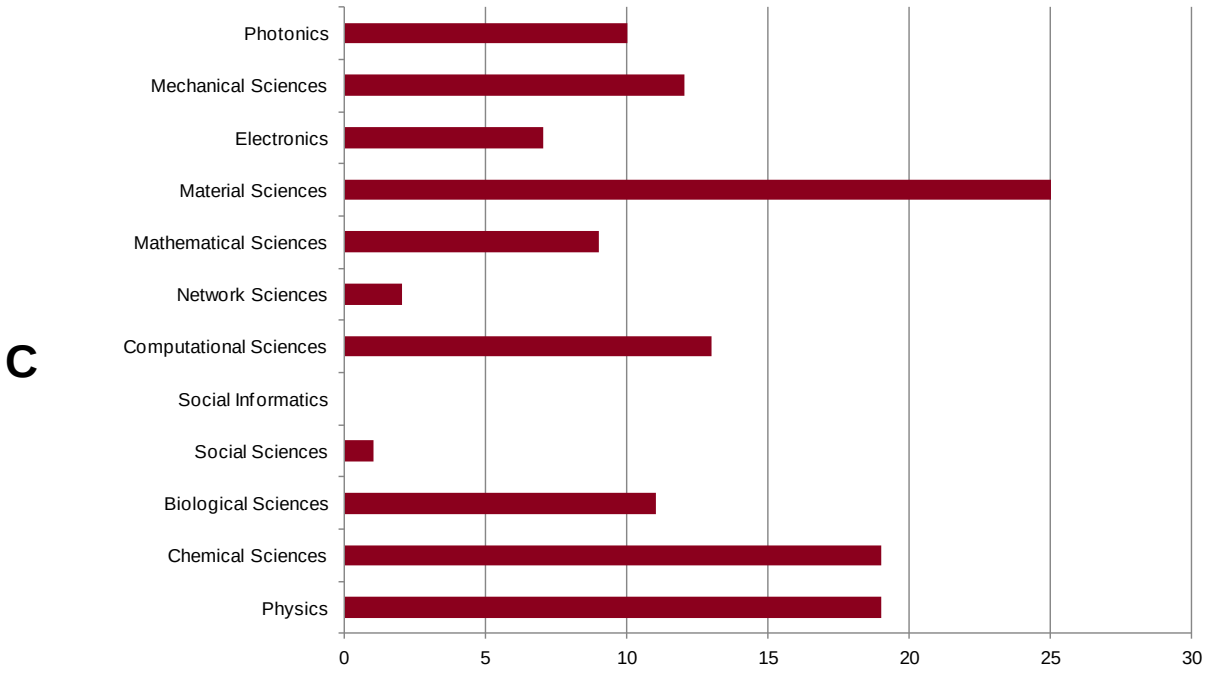


Fig. B-2 Instances chosen for Extramural Basic Research Campaign competencies for proficiency level 3 only

Table B-3 Personnel choosing Extramural Basic Research Campaign competencies for proficiency level 3 only

Extramural Basic Research	Civilians	Post Docs	Contractors	Total
Photonics	10	…	…	10
Mechanical sciences	12	…	…	12
Electronics	7	…	…	7
Materials research	25	…	…	25
Mathematical sciences	9	…	…	9
^Network sciences	2	…	…	2
Computational sciences	11	1	1	13
^Social informatics	0	…	…	0
^Social sciences	0	…	1	1
Biological sciences	10	…	1	11
Chemical sciences	14	…	5	19
Physics	19	…	…	19

^Less than 5 instances in collaborate

Appendix C. Human Sciences Campaign Data

This appendix appears in its original form, without editorial change.

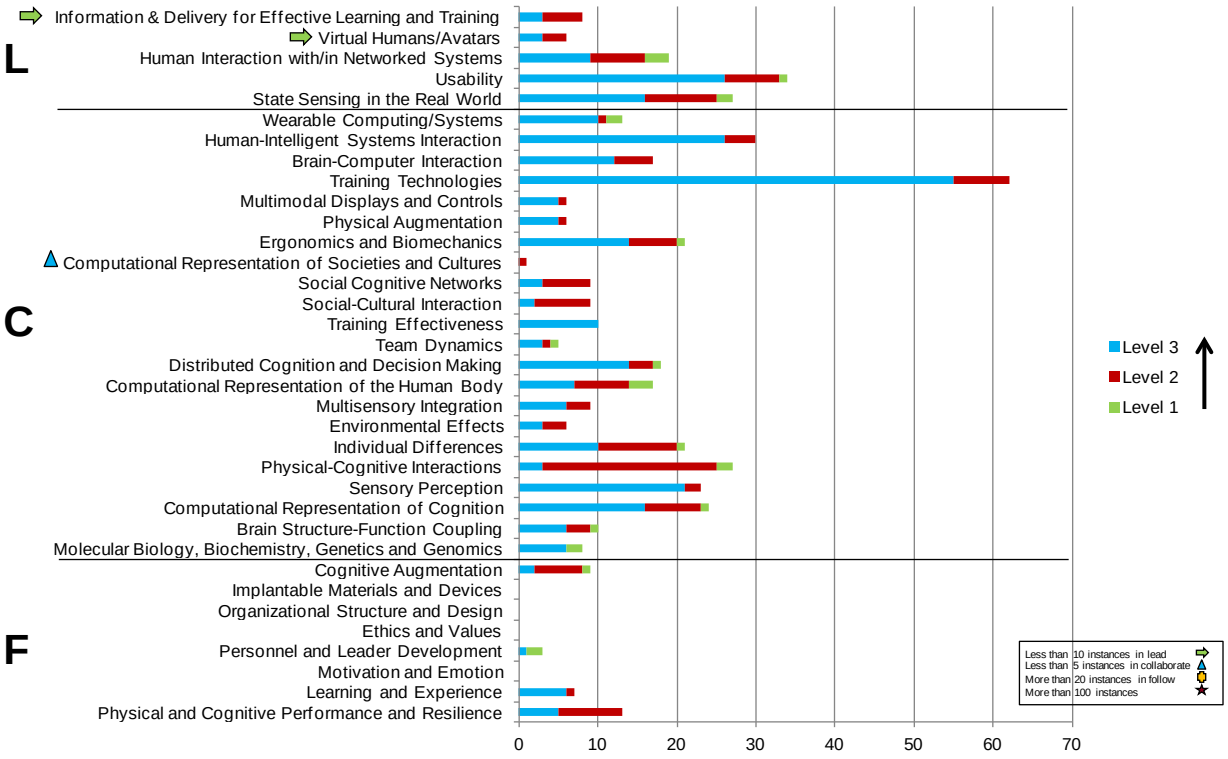


Fig. C-1 Instances chosen for Human Sciences Campaign Competencies

Table C-1 Personnel choosing Human Sciences Campaign competencies

Human Sciences	Civilians	Post Docs	Contractors	Total
>Information and delivery for effective learning and training	8	…	…	8
>Virtual humans/avatars	6	…	…	6
Human interaction with/in networked systems	13	2	4	19
Usability	33	…	1	34
State sensing in the real world	9	10	8	27
Wearable computing/systems	3	3	7	13
Human-intelligent systems interaction	12	9	9	30
Brain-computer interaction	5	7	5	17
Training technologies	42	…	20	62
Multimodal displays and controls	6	…	…	6
Physical augmentation	4	2	…	6
Ergonomics and biomechanics	15	3	3	21
^Computational representation of societies and cultures	1	…	…	1
Social cognitive networks	8	1	…	9
Social-cultural interaction	8	…	1	9
Training effectiveness	10	…	…	10
Team dynamics	3	2	…	5
Distributed cognition and decision making	11	3	4	18
Computational representation of the human body	11	…	6	17
Multisensory integration	9	…	…	9
Environmental effects	5	1	…	6
Individual differences	13	4	4	21
Physical-cognitive interactions	27	…	…	27
Sensory perception	23	…	…	23
Computational representation of cognition	10	9	5	24
Brain structure-function coupling	4	4	2	10
Molecular biology, biochemistry, genetics and genomics	7	…	1	8
Cognitive augmentation	8	1	…	9
Implantable materials and devices	0	…	…	0
Organizational structure and design	0	…	…	0
Ethics and values	0	…	…	0
Personnel and leader development	3	…	…	3
Motivation and emotion	0	…	…	0
Learning and experience	5	…	2	7
Physical and cognitive performance and resilience	12	…	1	13

>Less than 10 instances in lead

^Less than 5 instances in collaborate

Table C-2 Write-in competencies assigned to Human Sciences Campaign

Competency	Total
Audiology	1
Traumatic brain injury	1
Adaptive training research—intelligent tutoring systems	1
Dismounted soldier training	7
Ground platform training	1
Human factors integration tools	2
Human sciences—human use review	1
Information and delivery for effective learning	1
Intelligent tutoring systems—computer architectures	1
Intelligent tutoring systems—human factors	1
Intelligent tutoring systems—human systems interaction	1
Large scale distributed simulation for collective training	1
Live training and testing	2
Olfactory adaptation	1
Quantifying know transfer using sim-based trn methods	2
Simulation and training (dismounted soldier training)	1
Simulation and training (program management)	9
Small arms research	6
Synthetic environment for training	2

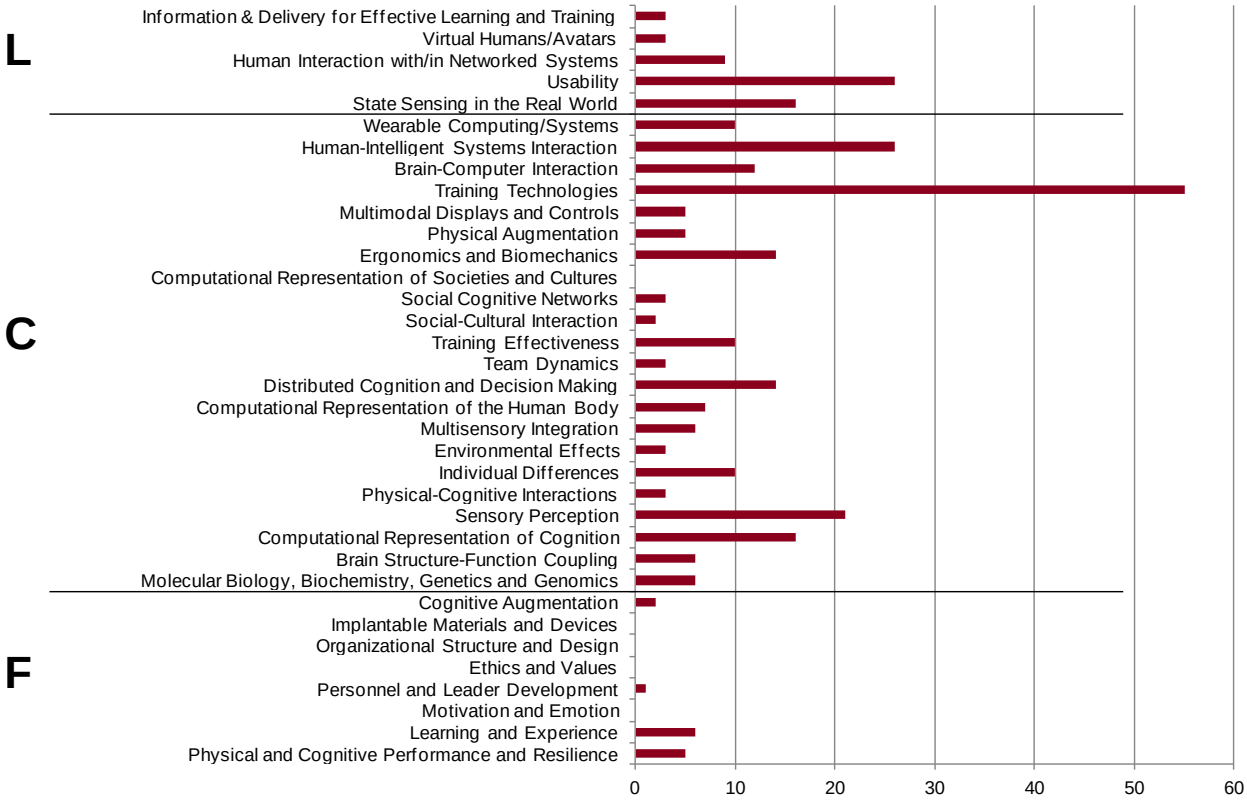


Fig. C-2 Instances chosen for Human Sciences Campaign Competencies for proficiency level 3 only

Table C-3 Personnel choosing Human Sciences Campaign competencies for proficiency level 3 only

Human Sciences	Civilians	Post Docs	Contractors	Total
>Information and delivery for effective learning and training	3	…	…	3
>Virtual humans/avatars	3	…	…	3
Human interaction with/in networked systems	7	…	2	9
Usability	25	…	1	26
State sensing in the real world	5	5	6	16
Wearable computing/systems	3	1	6	10
Human-intelligent systems interaction	11	8	7	26
Brain-computer interaction	4	5	3	12
Training technologies	39		16	55
Multimodal displays and controls	5	…	…	5
Physical augmentation	3	2	…	5
Ergonomics and biomechanics	11	3	…	14
^Computational representation of societies and cultures	0		…	0
Social cognitive networks	2	1	…	3
Social-cultural interaction	1	…	1	2
Training effectiveness	10	…	…	10
Team dynamics	3	…	…	3
Distributed cognition and decision making	8	2	4	14
Computational representation of the human body	4	…	3	7
Multisensory integration	6	…	…	6
Environmental effects	3	…	…	3
Individual differences	8	1	1	10
Physical-cognitive interactions	3	…	…	3
Sensory perception	20	1	…	21
Computational representation of cognition	6	6	4	16
Brain structure-function coupling	3	2	1	6
Molecular biology, biochemistry, genetics and genomics	5	…	1	6
Cognitive augmentation	2	…	…	2
Implantable materials and devices	0	…	…	0
Organizational structure and design	0	…	…	0
Ethics and values	0	…	…	0
Personnel and leader development	0	…	1	1
Motivation and emotion	0	…	…	0
Learning and experience	4	…	2	6
Physical and cognitive performance and resilience	5	…	…	5

>Less than 10 instances in lead

^Less than 5 instances in collaborate

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Appendix D. Information Sciences Campaign Data

This appendix appears in its original form, without editorial change.

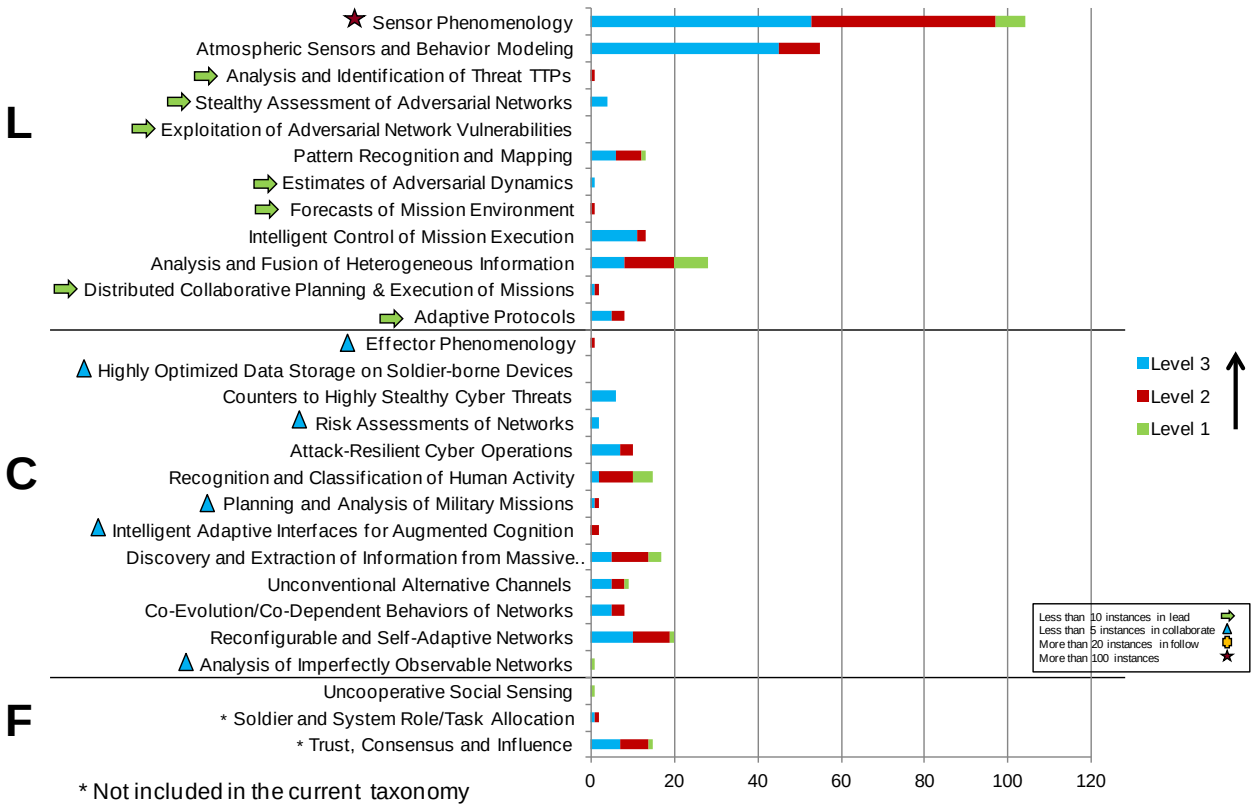

Fig. D-1 Instances chosen for Information Sciences Campaign competencies

Table D-1 Personnel choosing Information Sciences Campaign competencies

Information Sciences	Civilians	Post Docs	Contractors	Total
*Sensor phenomenology	98	1	5	104
Atmospheric sensors and behavior modeling	42	8	5	55
>Analysis and identification of threat TTPs	1	…	…	1
>Stealthy assessment of adversarial networks	4	…	…	4
>Exploitation of adversarial network vulnerabilities	0	…	…	0
Pattern recognition and mapping	12	…	1	13
>Estimates of adversarial dynamics	1	…	…	1
>Forecasts of mission environment	1	…	…	1
Intelligent control of mission execution	11	1	1	13
Analysis and fusion of heterogeneous information	26	…	2	28
>Distributed collaborative planning and execution of missions	2	…	…	2
>Adaptive protocols	7	1	…	8
^Effector phenomenology	1	…	…	1
^Highly optimized data storage on soldier-borne devices	0	…	…	0
Counters to highly stealthy cyber threats	6	…	…	6
^Risk assessments of networks	2	…	…	2
Attack-resilient cyber operations	10	…	…	10
Recognition and classification of human activity	15	…	…	15
^Planning and analysis of military missions	2	…	…	2
^Intelligent adaptive interfaces for augmented cognition	2	…	…	2
Discovery and extraction of information from massive data sets	14	1	2	17
Unconventional alternative channels	7	1	1	9
Co-evolution/co-dependent behaviors of networks	7	1	…	8
Reconfigurable and self-adaptive networks	15	1	4	20
^Analysis of imperfectly observable networks	1	…	…	1
Uncooperative social sensing	1	…	…	1
#Trust, consensus and influence	11	3	1	15
#Soldier and system role/task allocation	2	…	…	2

*More than 100 instances
>Less than 10 instances in lead
^Less than 5 instances in collaborate
#Not in the current taxonomy.

Table D-2 Write-in competencies assigned to the Informational Sciences Campaign

Competency	Total
Multi-modal sensor database	1
Fusion of multi-modal signature for human detection	1
Distributed processing across networks	2
Interoperability across sensors and networks	2
Distributed networks	1
Network signal processing	1
Cross modal face recognition	1
Distributed network processing	1
Distributed networks	1
Distributed processing across networks	1
Fusion of multi-modal signature for human detection	1
Hyperspectral sensor phenomenology	1
Image sampling and super-resolution	1
Interoperability across sensors and networks	2
Interoperability of RF systems	1
IR and visible video fusion	1
Multi-modal sensor database	1
Networks signal processing	1
Nonlinear classification and support vector machines	1
Sensors	8
Sensors and bio-inspired controls	2
Sensors and signal processing	1
Signal processing algorithms	1
Signal processing and cognitive radar	1
Sparse dictionary methods	1
Optimal networking	2
Atmospheric characterization and modeling	58
Infrastructure networking	2
Infrastructure networking documentation	1
Infrastructure networking/unclassified	2
Infrastructure networking/unclassified and classified	1
Software defined networking	1
Software defined networking (GENI system)	1
Sensors	4
Networks signal processing	1

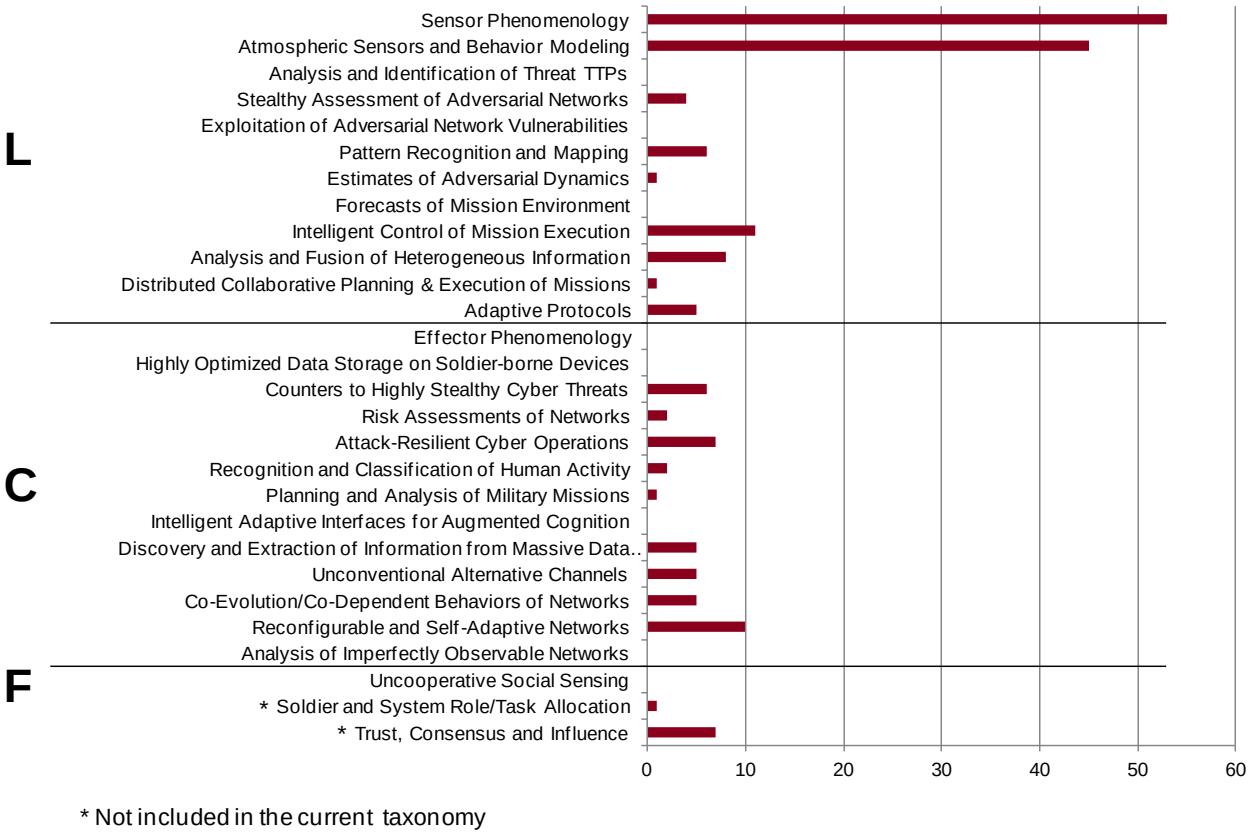

Fig. D-2 Instances chosen for Information Sciences Campaign competencies for proficiency level 3 only

Table D-3 Personnel choosing Information Sciences Campaign competencies for proficiency level 3 only

Information Sciences	Civilians	Post Docs	Contractors	Total
*Sensor phenomenology	51	…	2	53
Atmospheric sensors and behavior modeling	41	2	2	45
>Analysis and identification of threat TTPs	0	…	…	0
>Stealthy assessment of adversarial networks	4	…	…	4
>Exploitation of adversarial network vulnerabilities	0	…	…	0
Pattern recognition and mapping	6	…	…	6
>Estimates of adversarial dynamics	1	…	…	1
>Forecasts of mission environment	0	…	…	0
Intelligent control of mission execution	9	1	1	11
Analysis and fusion of heterogeneous information	8	…	…	8
>Distributed collaborative planning & execution of missions	1	…	…	1
>Adaptive protocols	4	1	…	5
^Effector phenomenology	0	…	…	0
^Highly optimized data storage on soldier-borne devices	0	…	…	0
Counters to highly stealthy cyber threats	6	…	…	6
^Risk assessments of networks	2	…	…	2
Attack-resilient cyber operations	7	…	…	7
Recognition and classification of human activity	2	…	…	2
^Planning and analysis of military missions	1	…	…	1
^Intelligent adaptive interfaces for augmented cognition	0	…	…	0
Discovery and extraction of information from massive data sets	5	…	…	5
Unconventional alternative channels	3	1	1	5
Co-evolution/co-dependent behaviors of networks	5	…	…	5
Reconfigurable and self-adaptive networks	8	…	2	10
^Analysis of imperfectly observable networks	0	…	…	0
Uncooperative social sensing	0	…	…	0
#Trust, consensus and influence	5	1	1	7
#Soldier and system role/task allocation	1	…	…	1

*More than 100 instances
>Less than 10 instances in lead
^Less than 5 instances in collaborate
#Not in the current taxonomy

Appendix E. Sciences for Lethality and Protection Campaign Data

This appendix appears in its original form, without editorial change.

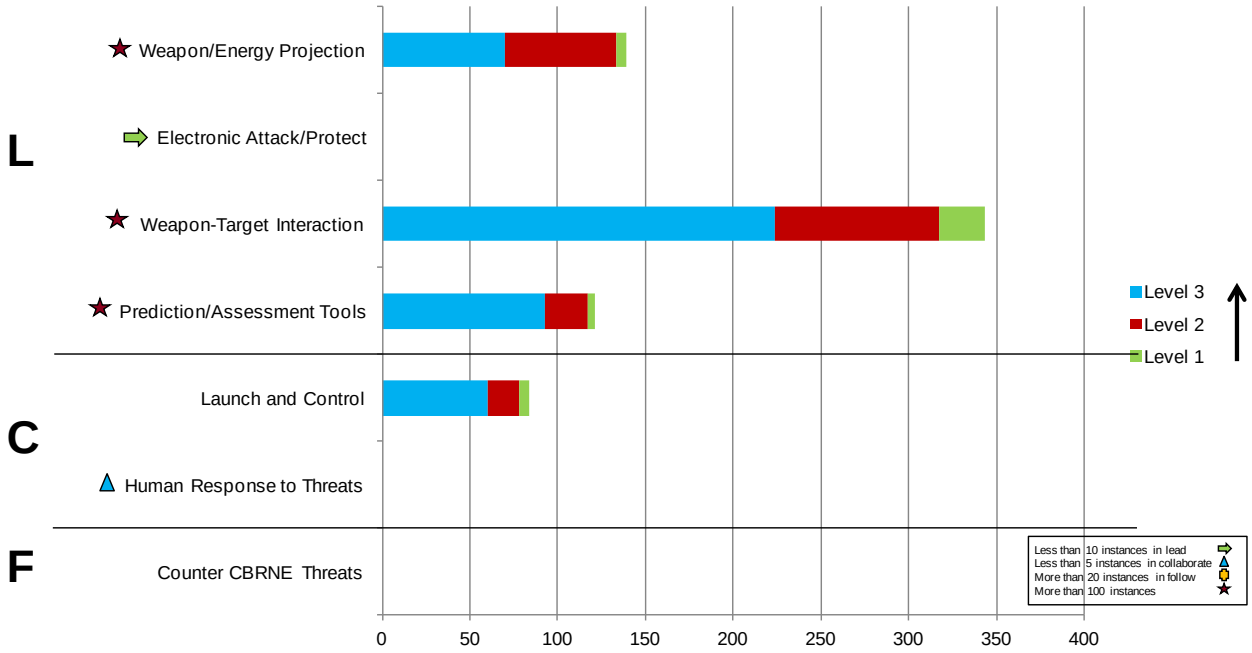

Fig. E-1 Instances chosen for Sciences for Lethality and Protection Campaign competencies as defined by campaign level 3 taxonomy

Table E-1 Personnel choosing Sciences for Lethality and Protection Campaign competencies as defined by level 3 taxonomy

Sciences for Lethality and Protection	Civilians	Post Docs	Contractors	Total
*Weapon/energy projection	121	…	18	139
Electronic attack/protect	…	…	…	…
*Weapon-target interaction	264	0	79	343
*Prediction/assessment tools	85	…	36	121
Launch and control	57	…	27	84
^Human response to threats	…	…	…	…
Counter CBRNE threats	…	…	…	…

*More than 100 instances
^Less than 5 instances in collaborate

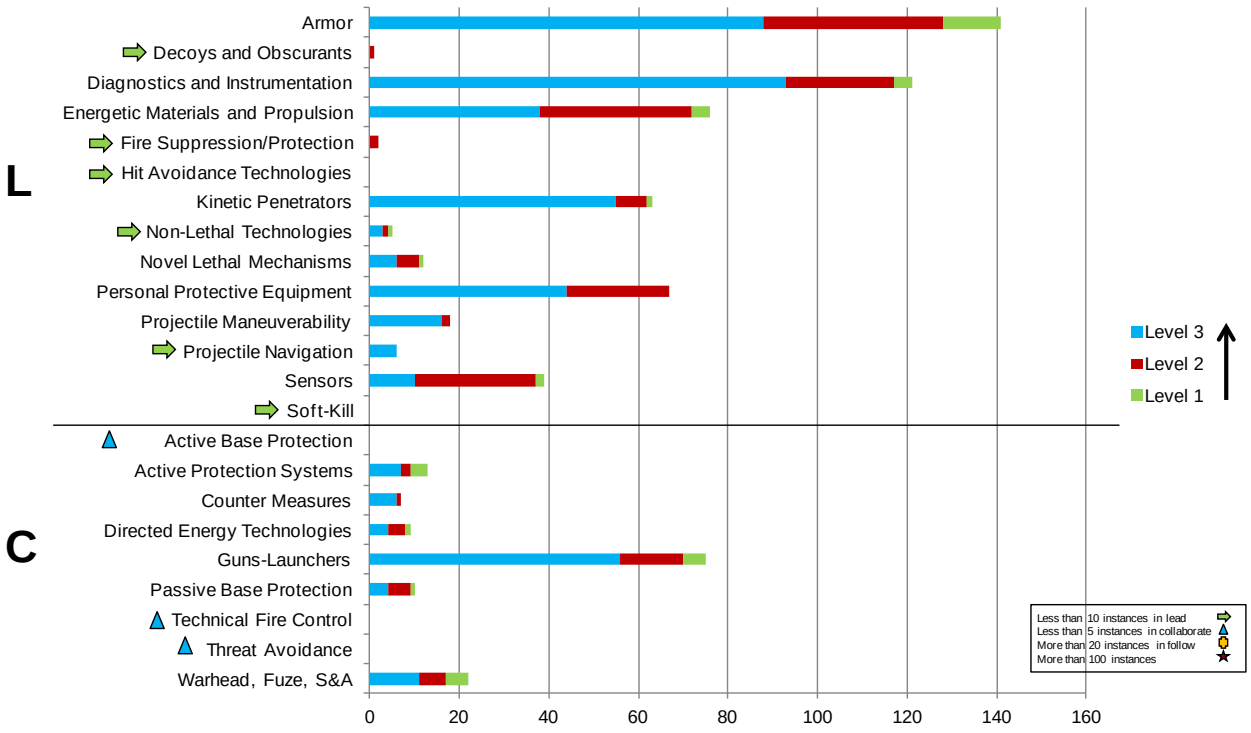

Fig. E-2 Instances chosen for Sciences for Lethality and Protection Campaign Competencies from list provided

Table E-2 Personnel choosing Sciences for Lethality and Protection Campaign competencies from list provided

Sciences for Lethality and Protection	Civilians	Post Docs	Contractors	Total
Armor	113	1	27	141
>Decoys and obscurants	1	…	…	1
Diagnostics and instrumentation	85	…	36	121
Energetic materials and propulsion	63	…	13	76
>Fire suppression/protection	2	…	…	2
>Hit avoidance technologies	0	…	…	0
Kinetic penetrators	50	…	13	63
>Non-lethal technologies	5	…	…	5
Novel lethal mechanisms	12	…	…	12
Personal protective equipment	49	…	18	67
Projectile maneuverability	16	…	2	18
>Projectile navigation	6	…	…	6
Sensors	39	…	…	39
>Soft-kill	0	…	…	0
^Active base protection	0	…	…	0
Active protection systems	12	…	1	13
Counter measures	7	…	…	7
Directed energy technologies	9	…	…	9
Guns-launchers	59	…	16	75
Passive base protection	10	…	…	10
^Technical fire control	0	…	…	0
^Threat avoidance	0	…	…	0
Warhead, fuze, S and A	22	…	…	22

>Less than 10 instances in lead

^Less than 5 instances in collaborate

Table E-3 Write-in competencies assigned to Sciences for Lethality and Protection Campaign

Competency	Total
Adhesive bonding and coating of energetics	1
Novel protection mechanisms	1
Life, safety, and health—ionizing and non-ionizing radiation	1
Life, safety, and health—occupational health/exposure control	1
Life, safety, and health—safety systems	1
RF electronic attack and directed energy	1
On-chip energetics	2

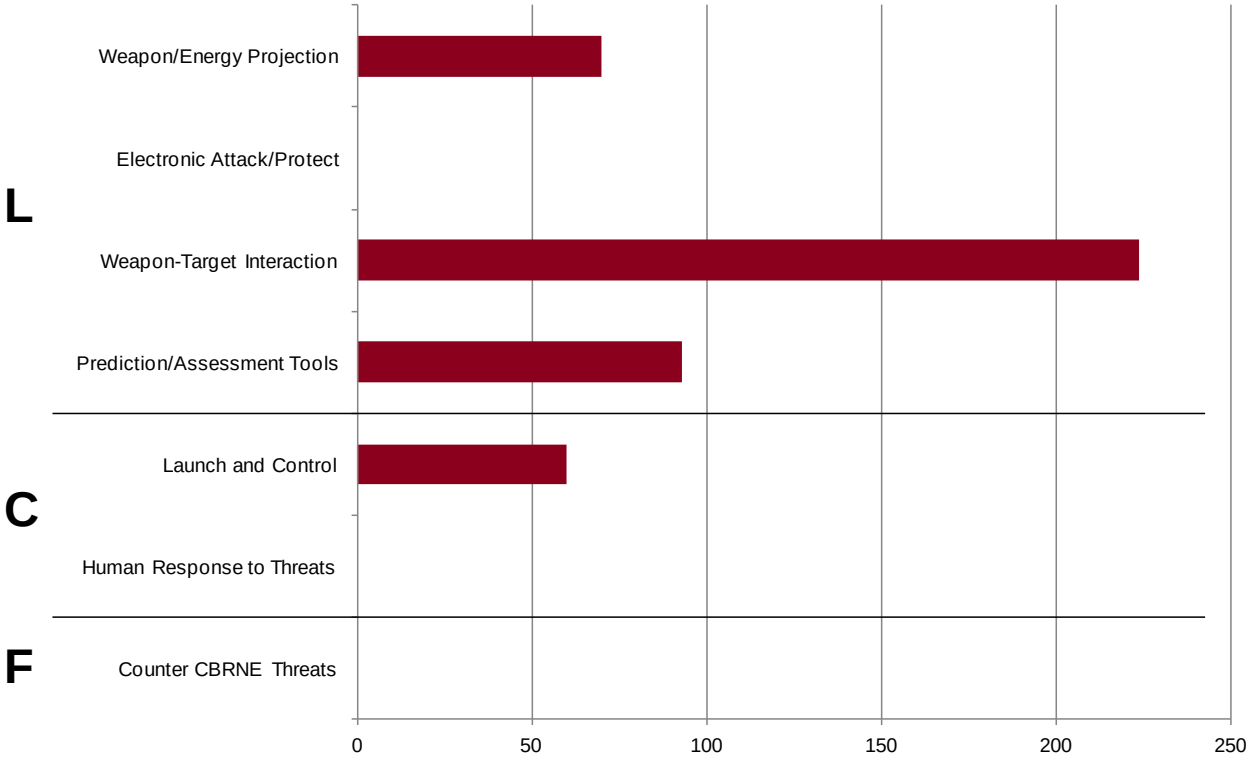

Fig. E-3 Instances chosen for Sciences for Lethality and Protection Campaign for proficiency level 3 only (campaign level 3 taxonomy)

Table E-4 Personnel choosing Sciences for Lethality and Protection Campaign competencies for proficiency level 3 only (campaign level 3 taxonomy)

Sciences for Lethality and Protection	Civilians	Post Docs	Contractors	Total
*Weapon/energy projection	70	…	…	70
>Electronic attack/protect	0	…	…	…
*Weapon-target interaction	224	…	…	224
*Prediction/assessment tools	93	…	…	93
Launch and control	60	…	…	60
^Human response to threats	…	…	…	…
Counter CBRNE threats	…	…	…	…

*More than 100 instances
>Less than 10 instances in lead
^Less than 5 instances in collaborate

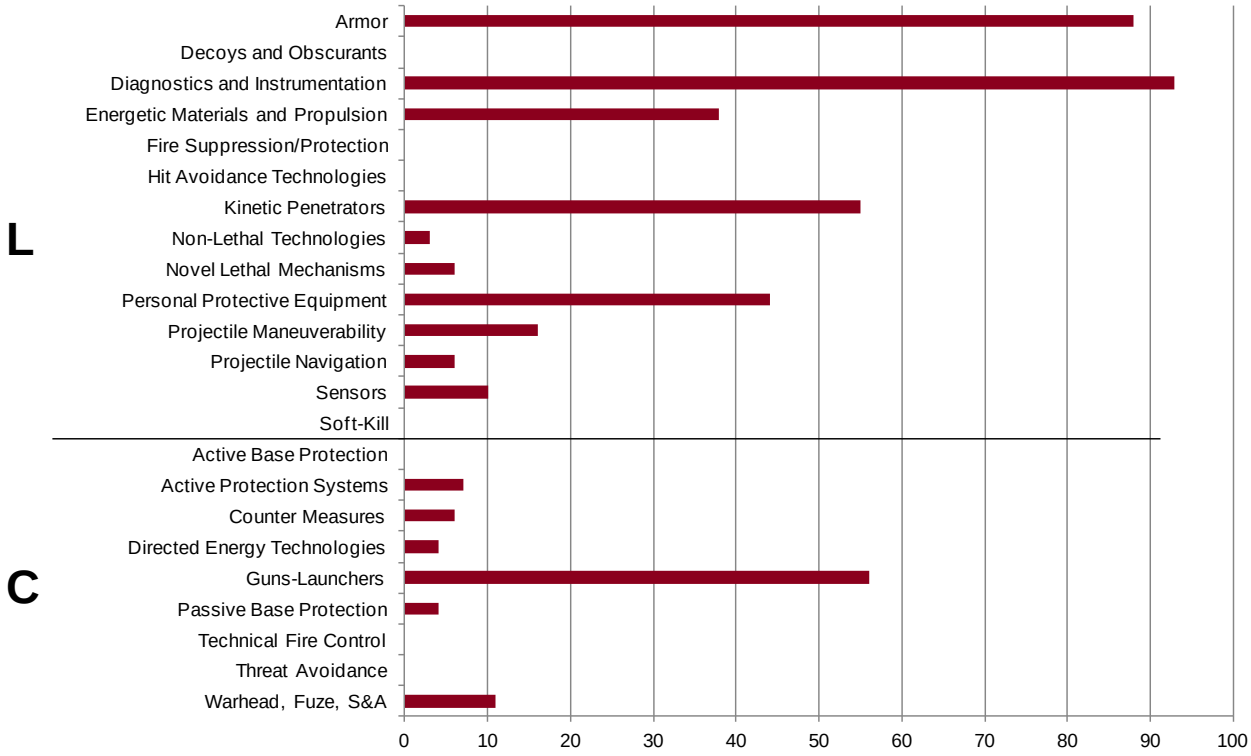

Fig. E-4 Instances chosen for Sciences for Lethality and Protection Campaign competencies for proficiency level 3 only (competency list created for data collection)

Fig. E-5 Personnel choosing Sciences for Lethality and Protection Campaign competencies for proficiency level 3 only (competency list created for data collection)

Sciences for Lethality and Protection	Civilians	Post Docs	Contractors	Total
Armor	86	…	2	88
>Decoys and obscurants	0	…	…	0
Diagnostics and instrumentation	64	…	29	93
Energetic materials and propulsion	36	…	2	38
>Fire suppression/protection	0	…	…	0
>Hit avoidance technologies	0	…	…	0
Kinetic penetrators	45	…	10	55
>Non-lethal technologies	3	…	…	3
Novel lethal mechanisms	6	…	…	6
Personal protective equipment	38	…	6	44
Projectile maneuverability	14	…	2	16
>Projectile navigation	6	…	…	6
Sensors	10	…	…	10
>Soft-kill	0	…	…	0
^Active base protection	0	…	…	0
Active protection systems	6	…	1	7
Counter measures	6	…	…	6
Directed energy technologies	4	…	…	4
Guns-Launchers	45	…	11	56
Passive base protection	4	…	…	4
^Technical fire control	0	…	…	0
^Threat avoidance	0	…	…	0
Warhead, fuze, S and A	11	…	…	11

>Less than 10 instances in lead

^Less than 5 instances in collaborate

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Appendix F. Sciences for Maneuver Campaign Data

This appendix appears in its original form, without editorial change.

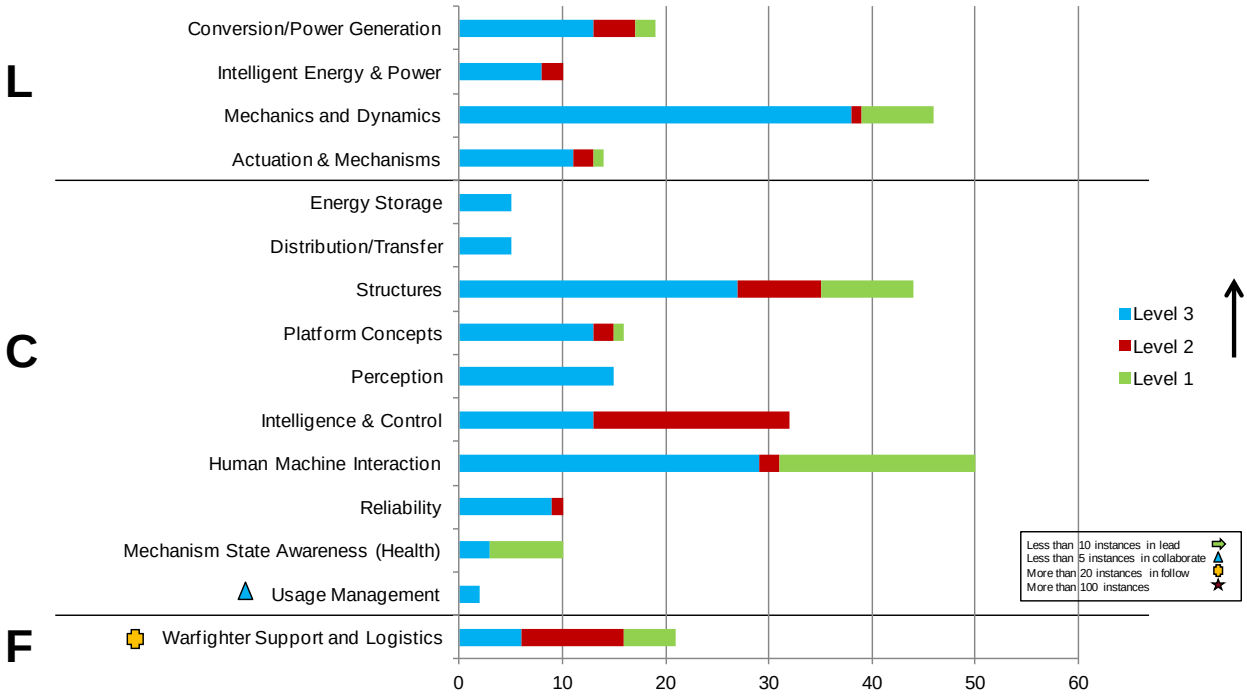

Fig. F-1 Instances chosen for Sciences for Maneuver Campaign competencies

Table F-1 Personnel choosing Sciences for Maneuver Campaign competencies

Sciences for Maneuver	Civilians	Post Docs	Contractors	Total
Conversion/power generation	19	…	…	19
Intelligent energy and power	10	…	…	10
Mechanics and dynamics	41	…	5	46
Actuation and mechanisms	11	…	3	14
Energy storage	5	…	…	5
Distribution/transfer	5	…	…	5
Structures	41	1	2	44
Platform concepts	16	…	…	16
Perception	14	1	…	15
Intelligence and control	28	1	3	32
Human machine interaction	39	…	11	50
Reliability	10	…	…	10
Mechanism state awareness (Health)	10	…	…	10
^Usage management	2	…	…	2
+Warfighter support and logistics	15	…	6	21

^Less than 5 instances in collaborate
+More than 20 instances in follow

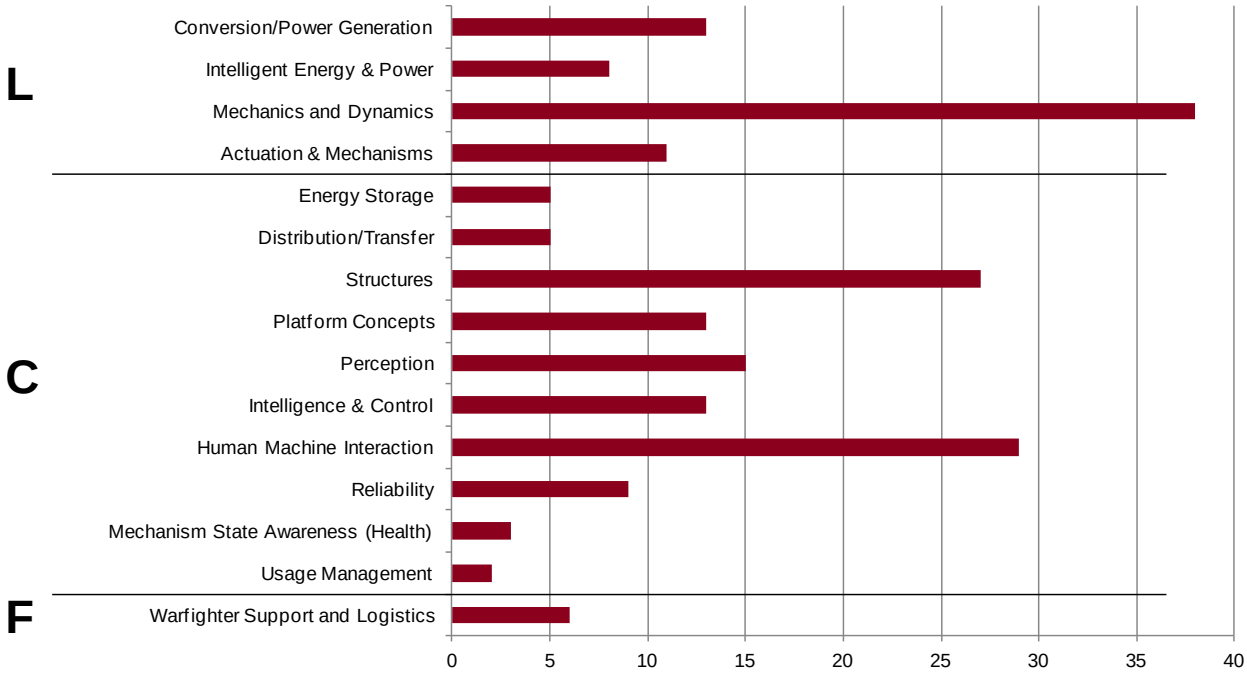

Fig. F-2 Instances chosen for Sciences for Maneuver Campaign competencies for proficiency level 3 only

Table F-2 Personnel choosing Sciences for Maneuver Campaign competencies for proficiency level 3 only

Sciences for Maneuver	Civilians	Post Docs	Contractors	Total
Conversion/power generation	13	…	…	13
Intelligent energy and power	8	…	…	8
Mechanics and dynamics	34	…	4	38
Actuation and mechanisms	10	…	1	11
Energy storage	5	…	…	5
Distribution/transfer	5	…	…	5
Structures	25	1	1	27
Platform concepts	13	…	…	13
Perception	14	1	…	15
Intelligence and control	11	…	2	13
Human machine interaction	20	…	9	29
Reliability	9	…	…	9
Mechanism state awareness (Health)	3	…	…	3
^Usage management	2	…	…	2
+Warfighter support and logistics	6	…	…	6

^Less than 5 instances in collaborate
+More than 20 instances in follow

Appendix G. Materials Research Campaign Data

This appendix appears in its original form, without editorial change.

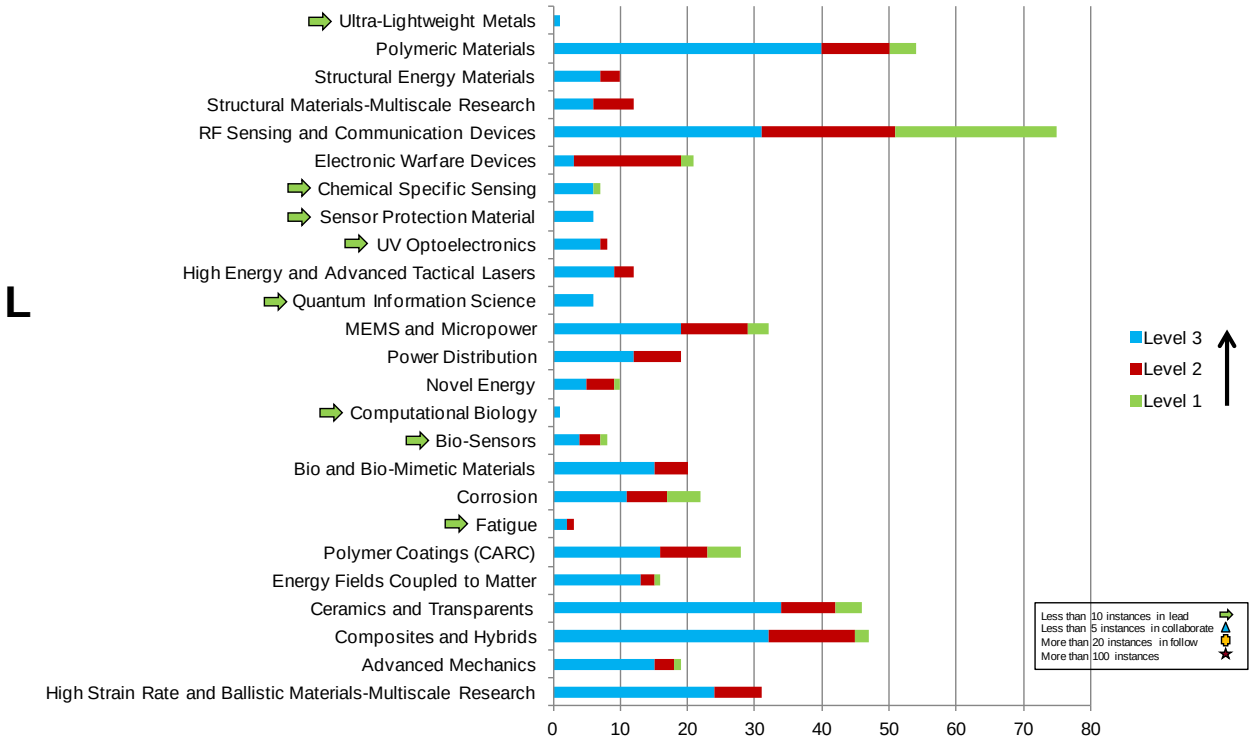

Fig. G-1 Instances chosen for Materials Research Campaign competencies for areas ARL will lead

Table G-1 Personnel choosing Materials Research Campaign competencies for areas ARL will lead

Materials Research	Civilians	Post Docs	Contractors	Total
>Ultra-lightweight metals	1	…	…	1
Polymeric materials	33	9	12	54
Structural energy materials	8	…	2	10
Structural materials-multiscale research	7	1	4	12
RF sensing and communication devices	75	…	…	75
Electronic warfare devices	21	…	…	21
>Chemical specific sensing	7	…	…	7
>Sensor protection material	6	…	…	6
>UV optoelectronics	7	…	1	8
High energy and advanced tactical lasers	12	…	…	12
>Quantum information science	5	…	1	6
MEMS and micropower	28	…	4	32
Power distribution	19	…	…	19
Novel energy	10	…	…	10
>Computational biology	1	…	…	1
Synthetic biology	9	1	2	12
>Bio-sensors	7	…	1	8
Bio and bio-mimetic materials	15	1	4	20
Corrosion	11	2	9	22
>Fatigue	3	…	…	3
Polymer coatings (CARC)	15	3	10	28
Energy fields coupled to matter	10	3	3	16
Ceramics and transparents	28	5	13	46
Composites and hybrids	28	3	16	47
Advanced mechanics	13	3	3	19
High strain rate and ballistic materials-multiscale research	24	2	5	31

>Less than 10 instances in lead

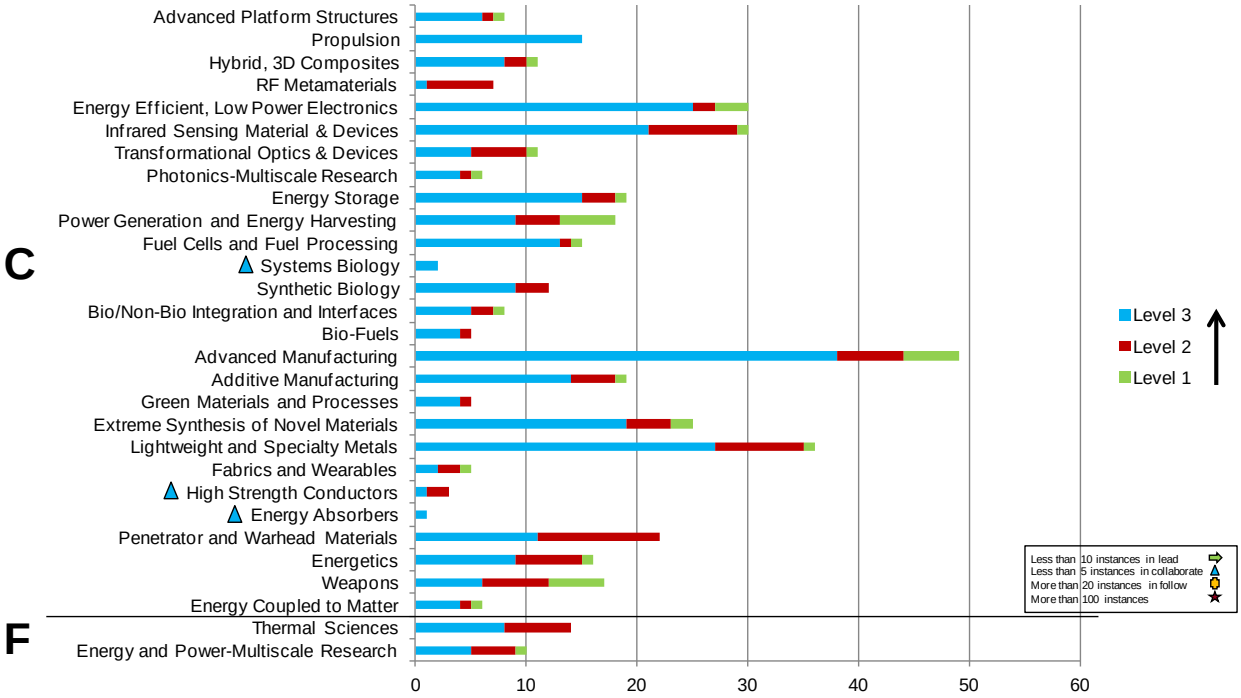

Fig. G-2 Instances chosen for Materials Research Campaign competencies in areas where ARL will collaborate and follow

Table G-2 Personnel choosing Materials Research Campaign competencies in areas where ARL will collaborate and follow

Materials Research	Civilians	Post Docs	Contractors	Total
Advanced platform structures	7	…	1	8
Propulsion	12	1	2	15
Hybrid, 3D composites	10	1	…	11
RF metamaterials	7	…	…	7
Energy efficient, low power electronics	30	…	…	30
Infrared sensing material and devices	30	…	…	30
Transformational optics and devices	10	…	1	11
Photonics-multiscale research	4	…	2	6
Energy storage	18	1	…	19
Power generation and energy harvesting	18	…	…	18
Fuel cells and fuel processing	12	3	…	15
^Systems biology	2	…	…	2
Synthetic biology	9	1	2	12
Bio/non-bio integration and interfaces	8	…	…	8
Bio-fuels	5	…	…	5
Advanced manufacturing	41	2	6	49
Additive manufacturing	11	1	7	19
Green materials and processes	5	…	…	5
Extreme synthesis of novel materials	16	4	5	25
Lightweight and specialty metals	23	2	11	36
Fabrics and wearables	4	…	1	5
^High strength conductors	3	…	…	3
^Energy absorbers	1	…	…	1
Penetrator and warhead materials	18	1	3	22
Energetics	15	…	1	16
Weapons	11	…	6	17
Energy coupled to matter	4	1	1	6
Thermal sciences	13	1	…	14
Energy and power-multiscale research	9	…	1	10

^Less than 5 instances in collaborate

Table G-3 Write-in competencies assigned to the Materials Research Campaign

Competency	Total
Antennas	4
Electronic warfare	9
Embedded systems	1
Empirical RF device modeling	1
IC design	1
MMIC design	1
mMW sensors	3
Photographic technologies	1
RF device linearization	1
RF devices	2
RF electronics	3
Sensitive RF technology	3
Semiconductor device technology development	1
Thermal design for electronics	1
2D electronic materials	4
3D fusion and viewing	1
Field effects on energy conversion	1
Materials—ultra-energetic materials, nuclear reactions and radiation detection	1
Materials—ultra-energetic materials and radiation detection	1
Materials—wide band gap Electronic devices reliability	1
MEMS sensors for position, navigation, and timing	2
Micro and nano devices	1
Piezoelectric MEMS	6
Radar and RF phenomenology	1
Radar hardware design and development	2
Radar hardware development and testing	1
Radar signal processing	4
Radar signature modeling	4
RF circuit board design and layout	1
Semiconductor materials and devices	13
Microbiology	1
Adhesives and interfaces	1
Atomic physics	1
Detonation physics, shock physics, detonation science	1
Detonation science	2
Disruptive energetics	1
Electromagnetics	1
Energetic material synthesis	2
Environmental weathering	1
Explosives analysis and formulation	2
Explosives dynamics experimentation	3
Explosives formulation	1
Explosives formulation and processing	1

Table G-3…Write-in competencies assigned to the Materials Research Campaign (continued)

Competency	Total
Explosives processing	2
Insensitive explosives and munitions	1
Materials sciences—non-destructive inspection	3
Materials sciences—supersonic particle deposition - cold spray	1
Materials sciences—materials databases and informatics	1
Materials specifications and standards	2
Polymer physics	1
Polymer processing	1
Quantum and atomistic modeling of materials	1
Transport through polymers	1
Energy absorbers	2
Computational material modeling	1
Powder metallurgy	1
Tribology	1
Non-destructive inspection	1
Advanced semiconductor metrology	1
Analog, mixed signal, and RFIC design	1
Sensitive RF measurements and testing	1

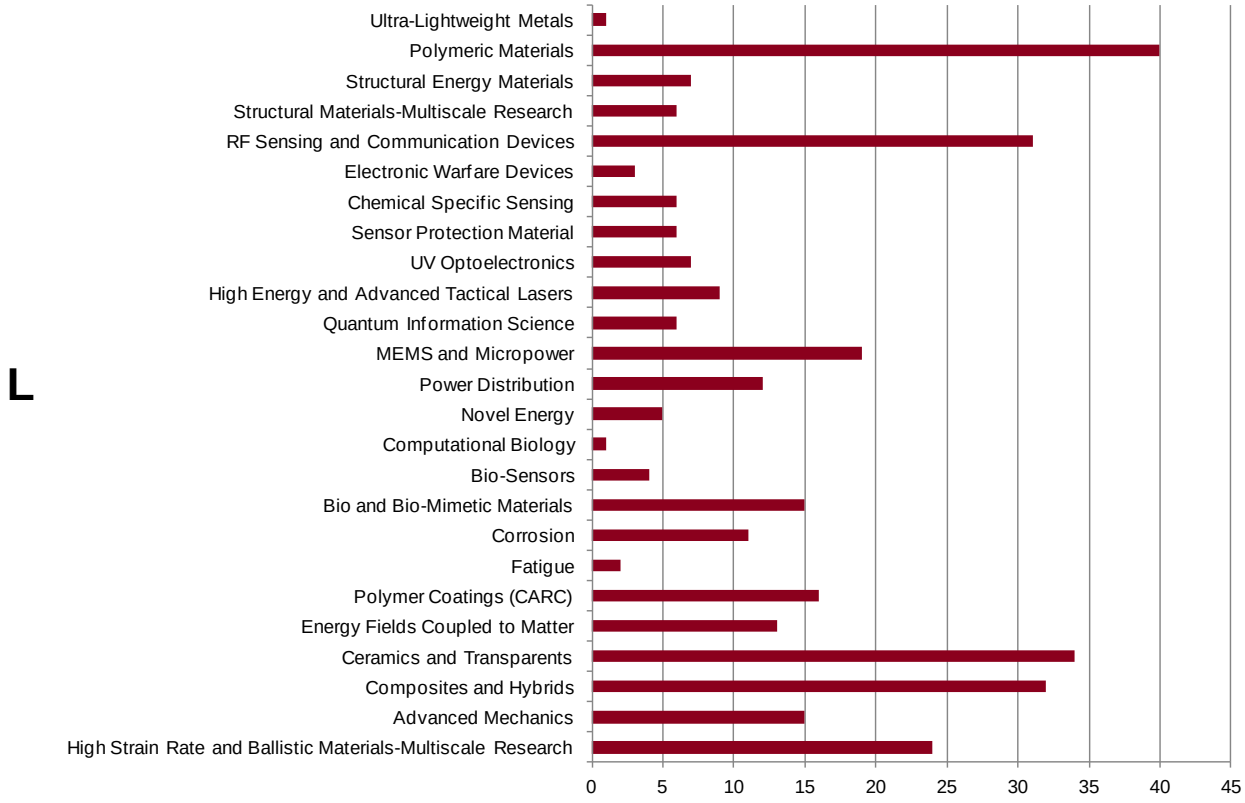

Fig. G-3 Instances chosen for Materials Research Campaign competencies for proficiency level 3 only in areas where ARL will lead

Table G-4 Personnel choosing Materials Research Campaign competencies for proficiency level 3 only in areas where ARL will lead

Materials Research	Civilians	Post Docs	Contractors	Total
>Ultra-lightweight metals	1	…	…	1
Polymeric materials	33	…	7	40
Structural energy materials	7	…	…	7
Structural materials-multiscale research	5	…	1	6
RF sensing and communication devices	31	…	…	31
Electronic warfare devices	3	…	…	3
>Chemical specific sensing	6	…	…	6
>Sensor protection material	6	…	…	6
>UV optoelectronics	6	…	1	7
High energy and advanced tactical lasers	9	…	…	9
>Quantum information science	5	…	1	6
MEMS and micropower	18	…	1	19
Power distribution	12	…	…	12
Novel energy	5	…	…	5
>Computational biology	1	…	…	1
Synthetic biology	9	…	…	9
>Bio-sensors	3	…	1	4
Bio and bio-mimetic materials	12	…	3	15
Corrosion	9	…	2	11
>Fatigue	2	…	…	2
Polymer coatings (CARC)	14	…	2	16
Energy fields coupled to matter	11	…	2	13
Ceramics and transparents	27	…	7	34
Composites and hybrids	24	…	8	32
Advanced mechanics	14	…	1	15
High strain rate and ballistic materials-multiscale research	20	…	4	24

>Less than 10 instances in lead

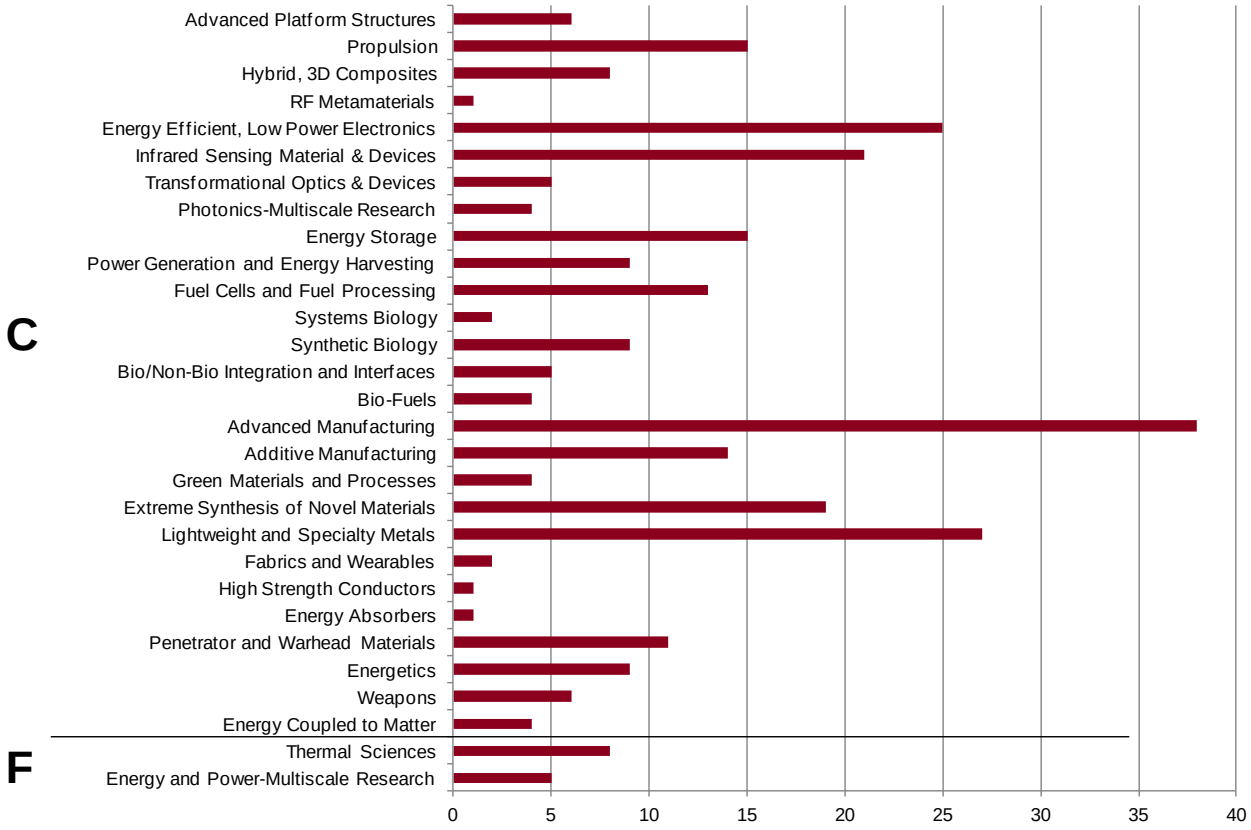

Fig. G-4 Instances chosen for Materials Research Campaign competencies for proficiency level 3 only in areas where ARL will collaboration and follow

Table G-5 Personnel choosing Materials Research Campaign competencies for proficiency level 3 only in areas where ARL will collaborate and follow

Materials Research	Civilians	Post Docs	Contractors	Total
Advanced platform structures	6	…	…	6
Propulsion	12	1	2	15
Hybrid, 3D composites	8	…	…	8
RF metamaterials	1	…	…	1
Energy efficient, low power electronics	25	…	…	25
Infrared sensing material and devices	21	…	…	21
Transformational optics and devices	4	…	1	5
Photonics-multiscale research	2	…	2	4
Energy storage	15	…	…	15
Power generation and energy harvesting	9	…	…	9
Fuel cells and fuel processing	11	2	…	13
^Systems biology	2	…	…	2
Bio/non-bio integration and interfaces	5	…	…	5
Bio-fuels	4	…	…	4
Advanced manufacturing	35	…	3	38
Additive manufacturing	6	…	8	14
Green materials and processes	4	…	…	4
Extreme synthesis of novel materials	15	…	4	19
Lightweight and specialty metals	21	…	6	27
Fabrics and wearables	2	…	…	2
^High strength conductors	1	…	…	1
^Energy absorbers	1	…	…	1
Penetrator and warhead materials	11	…	…	11
Energetics	8	…	1	9
Weapons	6	…	…	6
Energy coupled to matter	3	…	1	4
Thermal sciences	7	1	…	8
Energy and power-multiscale research	4	…	1	5

^Less than 5 instances in collaborate

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Appendix H. Computational Sciences Campaign Data

This appendix appears in its original form, without editorial change.

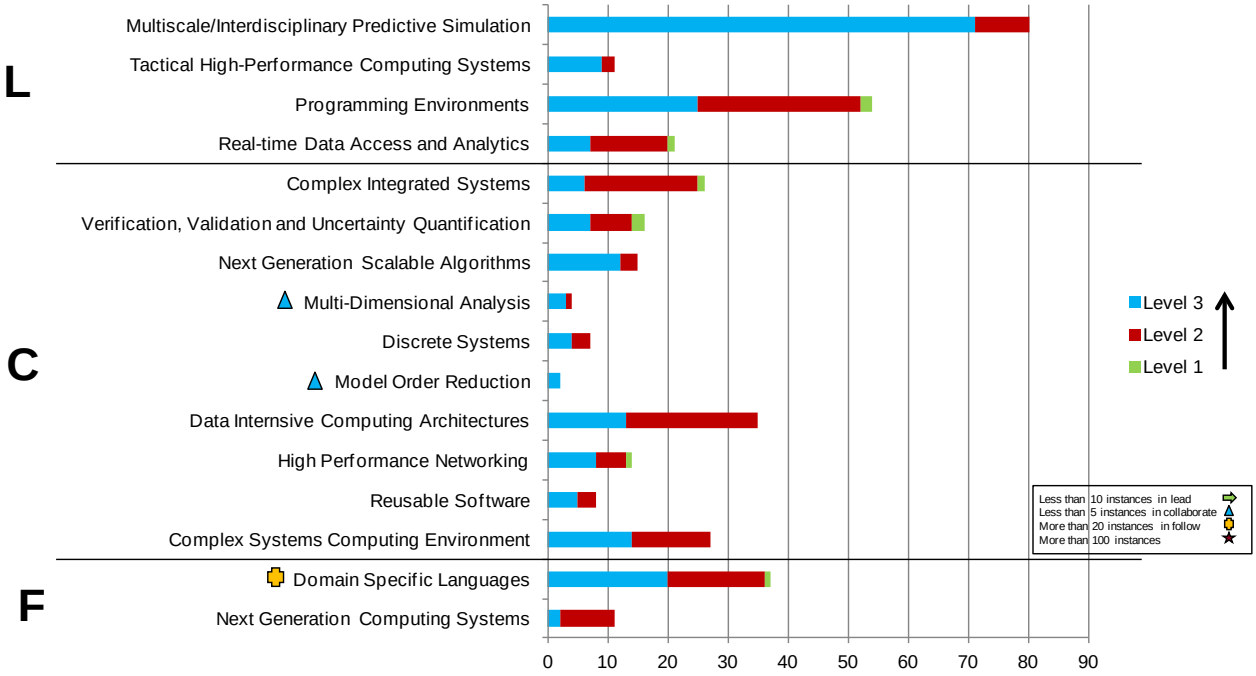

Fig. H-1 Instances chosen for Computational Sciences Campaign competencies

Table H-1 Personnel choosing Computational Sciences Campaign competencies

Computational Sciences	Civilians	Post Docs	Contractors	Total
Multiscale/interdisciplinary predictive simulation	46	12	22	80
Tactical high-performance computing systems	10	1	…	11
Programming environments	34	…	20	54
Real-time data access and analytics	18	…	3	21
Complex integrated systems	25	…	1	26
Verification, validation and uncertainty quantification	16	…	…	16
Next generation scalable algorithms	8	2	5	15
^Multi-dimensional analysis	4	…	…	4
Discrete systems	3	1	3	7
^Model order reduction	0	…	2	2
Data intensive computing architectures	17	…	18	35
High performance networking	9	…	5	14
Reusable software	3	…	5	8
Complex systems computing environment	14	…	13	27
+Domain specific languages	27	…	10	37
Next generation computing systems	5	…	6	11

^Less than 5 instances in collaborate
+More than 20 instances in follow

Table H-2 Write-in competencies assigned to Computational Sciences Campaign

Competency	Total
Multiscale/inter-predictive simulation	1
Semi-supervised image classification	1

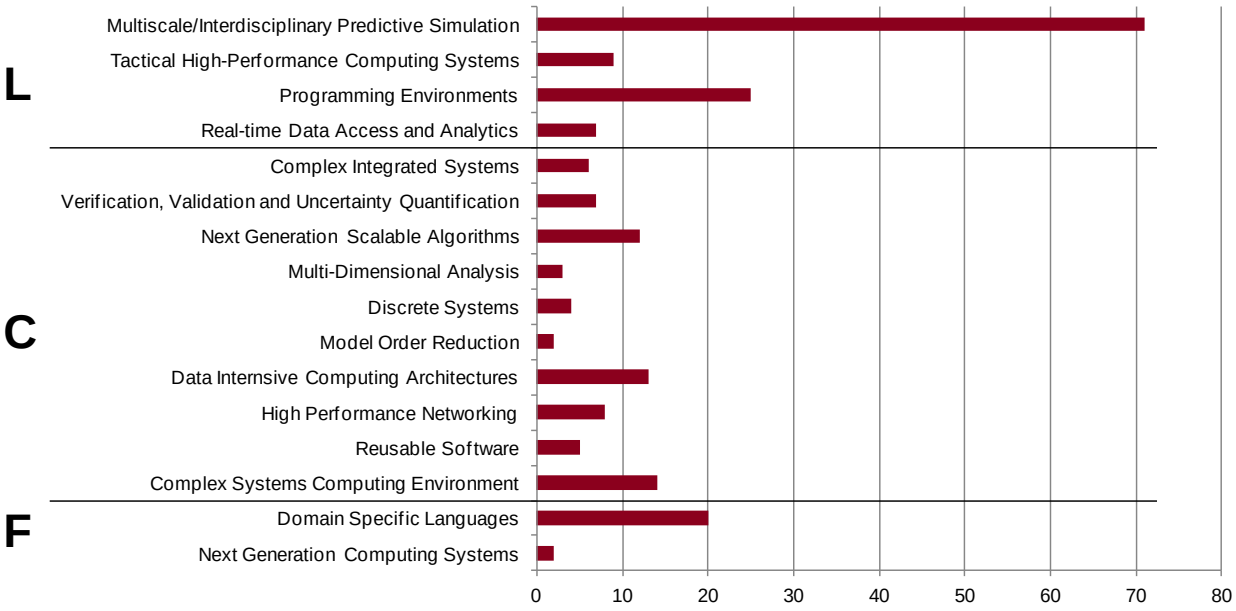

Fig. H-2 Instances chosen for Computational Sciences Campaign competencies for proficiency level 3 only

Table H-3 Personnel choosing Computational Sciences Campaign competencies for proficiency level 3 only

Computational Sciences	Civilians	Post Docs	Contractors	Total
Multiscale/interdisciplinary predictive simulation	54	1	16	71
Tactical high-performance computing systems	6	1	2	9
Programming environments	18	…	7	25
Real-time data access and analytics	6	…	1	7
Complex integrated systems	6	…	…	6
Verification, validation and uncertainty quantification	7	…	…	7
Next generation scalable algorithms	8	1	3	12
^Multi-dimensional analysis	3	…	…	3
Discrete systems	1	1	2	4
^Model order reduction	2	…	…	2
Data intensive computing architectures	8	…	5	13
High performance networking	5	…	3	8
Reusable software	2	…	3	5
Complex systems computing environment	10	…	4	14
+Domain specific languages	13	…	7	20
Next generation computing systems	1	…	1	2

^Less than 5 instances in collaborate
+More than 20 instances in follow

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Appendix I. Assessment and Analysis Campaign Data

This appendix appears in its original form, without editorial change.

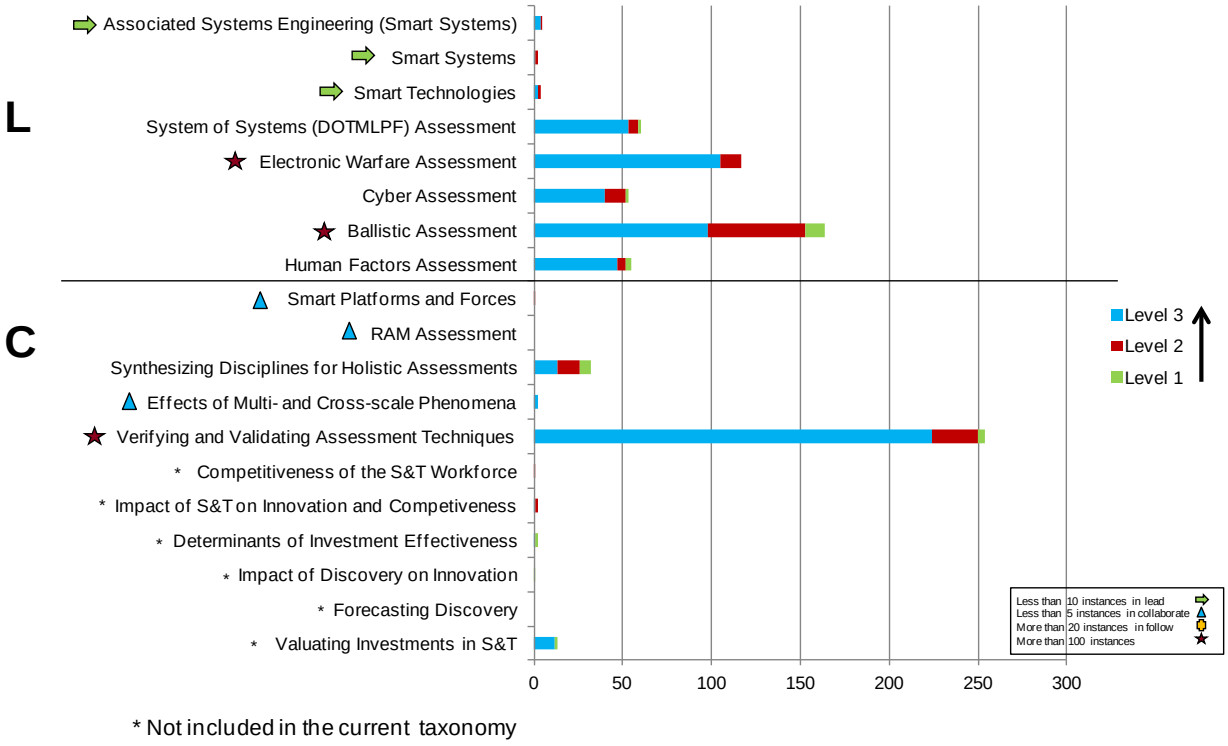


Fig. I-1 Instances chosen for Assessment and Analysis Campaign competencies

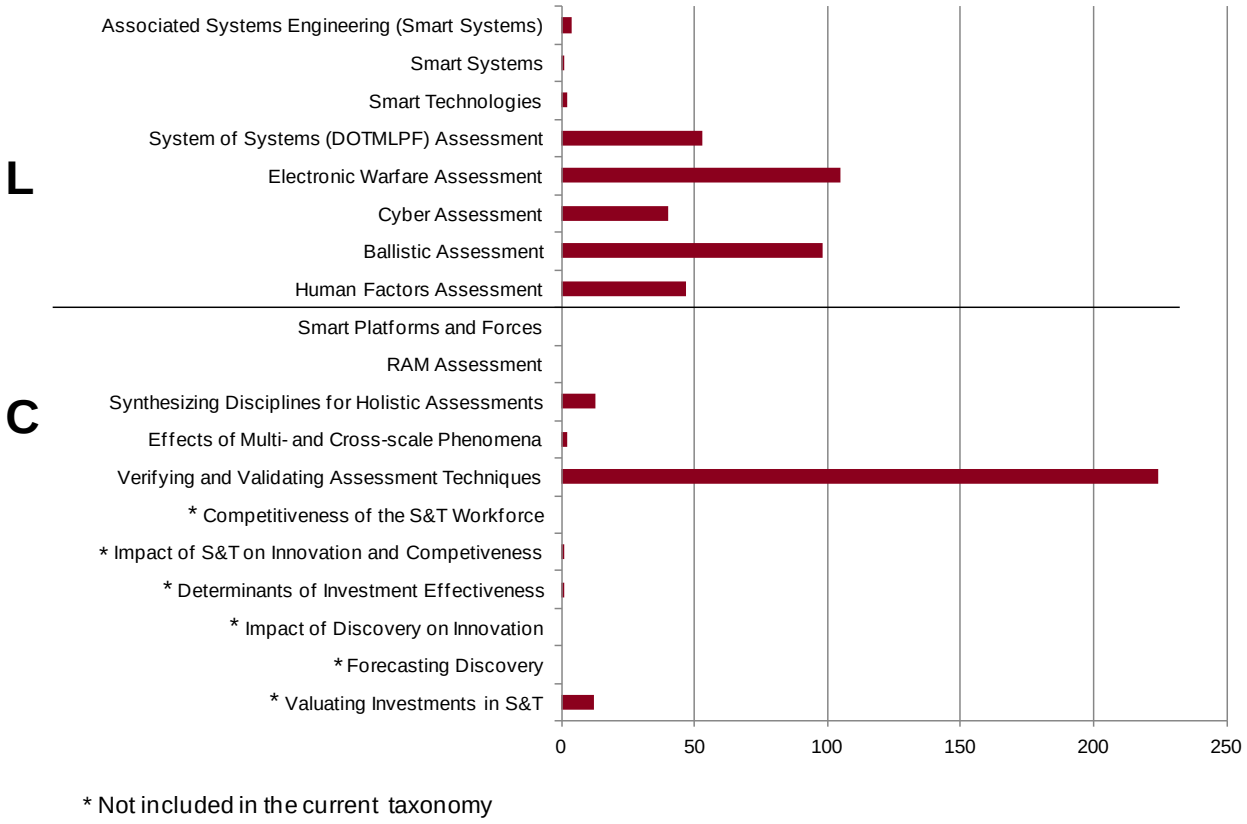
Table I-1 Personnel choosing Assessment and Analysis Campaign competencies

Assessment and Analysis	Civilians	Post Docs	Contractors	Total
>Associated systems engineering (smart systems)	5	…	…	5
>Smart systems	2	…	…	2
>Smart technologies	3	…	1	4
System of systems (DOTMLPF) assessment	36	…	24	60
*Electronic warfare assessment	76	…	41	117
Cyber assessment	44	…	9	53
*Ballistic assessment	136	…	28	164
Human factors assessment	55	…	…	55
^Smart platforms and forces	1	…	…	1
^RAM assessment	0	…	…	0
Synthesizing disciplines for holistic assessments	24	…	8	32
^Effects of multi- and cross-scale phenomena	2	…	…	2
*Verifying and validating assessment techniques	242	3	9	254
#Competitiveness of the S and T workforce	1	…	…	1
#Impact of S&T on innovation and competiveness	2	…	…	2
#Determinants of Investment effectiveness	2	…	…	2
#Impact of discovery on innovation	1	…	…	1
#Forecasting discovery	0	…	…	0
#Valuating Investments in S and T	13	…	…	13

*More than 100 instances
>Less than 10 instances in lead
^Less than 5 instances in collaborate
#Not in the current taxonomy

Table I-2 Write-in competencies for Assessment and Analysis Campaign

Competency	Total
Assessment and analysis—methodology development	4
Assessment and analysis, modeling and simulation development	9
Assessment and analysis, modeling and simulation development, computer-aided geometry techniques	5
Assessment and analysis, modeling and simulation development, massively parallel techniques	6
Battlefield injury mechanisms	1



* Not included in the current taxonomy

Fig. I-2 Instances chosen for Assessment and Analysis Campaign competencies for proficiency level 3 only

Table I-3 Personnel choosing Assessment and Analysis Campaign competencies for proficiency level 3 only

Assessment and Analysis	Civilians	Post Docs	Contractors	Total
>Associated systems engineering (smart systems)	4	…	…	4
>Smart systems	1	…	…	1
>Smart technologies	2	…	…	2
System of systems (DOTMLPF) assessment	30	…	23	53
*Electronic warfare assessment	65	…	40	105
Cyber assessment	31	…	9	40
*Ballistic assessment	84	…	14	98
Human factors assessment	47	…	…	47
^Smart platforms and forces	0	…	…	0
^RAM assessment	0	…	…	0
Synthesizing disciplines for holistic assessments	11	…	2	13
^Effects of multi- and cross-scale phenomena	2	…	…	2
*Verifying and validating assessment techniques	216	2	6	224
#Competitiveness of the S and T workforce	0	…	…	0
#Impact of S and T on innovation and competiveness	1	…	…	1
#Determinants of investment effectiveness	1	…	…	1
#Impact of discovery on innovation	0	…	…	0
#Forecasting discovery	0	…	…	0
#Valuating investments in S and T	12	…	…	12

>Less than 10 instances in lead
*More than 100 instances
^Less than 5 instances in collaborate
#NOT in the current taxonomy

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List of Symbols, Abbreviations, and Acronyms

ARL	US Army Research Laboratory
HRED	Human Research and Engineering Directorate
KSA	knowledge, skill, and ability
RDECOM	US Army Research, Development and Engineering Command
S&E	Scientist and Engineer
S&T	science and technology
SLaP	Sciences for Lethality and Protection
SWC	specialty work code
WMRD	Weapons and Materials Research Directorate

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2 (PDF) DIRECTOR US ARMY RESEARCH LAB RDRL CIO LL IMAL HRA MAIL & RECORDS MGMT

1 (PDF) GOVT PRINTG OFC A MALHOTRA

1 (PDF) ARMY RSCH LABORATORY HRED RDRL HRM D T DAVIS

3 (PDF) ARMY RSCH LABORATORY ARO RDRL RO LTC T RYAN D SKATRUD RDRL ROE T DOLIGALSKI

24 (PDF) DIR USARL RDRL CI J PELLEGRINO RDRL CII B BROOME RDRL D T RUSSELL RDRL DP V EMERY T ROSENBERGER RDRL HR L ALLENDER J WOJCIECHOWSKI RDRL HRS J LOCKETT RDRL HRS E D HEADLEY RDRL LO T KINES RDRL LOH D HAWKINS S HICKMAN J LAROCHE N SIMON RDRL SE P PERCONTI RDRL SER J MAIT RDRL SES E N NASRABADI RDRL SL P TANENBAUM J BEILFUSS RDRL VT M VALCO S WILKERSON RDRL VTV E HABTOUR RDRL WM P BAKER RDRL WML E P WEINACHT